Vol. 4. July, 1938. No. 3.

THE

NEW GUINEA
AGRICULTURAL GAZETTE

DEPARTMENT OF AGRICULTURE.
TERRITORY OF NEW GUINEA.

RABAUL.

By Authority:
L. F. Johnston, Commonwealth Government Printer, Canberra.
(Printed in Australia.)

PRICE: ONE SHILLING.

3538.

TERRITORY OF NEW GUINEA.

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THE

New Guinea Agricultural Gazette.*

Vol. 4. JULY, 1938. **No. 3.**

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* The following numbers have been issued—
Vol. 1 No. 1.—October, 1935.
Vol. 2 Nos. 1, 2 and 3.—January, October and December, 1936.
Vol. 3 Nos. 1 and 2.—April and December, 1937.
Vol. 4, Nos. 1 and 2.—January and April, 1938.

3538.

EDITORIAL.

In this issue results are given of preliminary tests with insecticides against *Sexava spp.* (coco-nut tree-hopper). Since this was written the power dusting machine has been received and field trials will be proceeded with as soon as possible, but as it will be some time before these can be completed, the results referred to are published at this stage to show the line of investigation that has been started.

The value of coco-nut improvement by seed selection is dealt with at length and it is generally recognized that in these times of specialization in agricultural practice and keen trade competition, the most careful attention to detail is essential in order to obtain the best from agricultural pursuits.

A contribution on the dwarf coco-nut has been submitted by Mr. Hall, Madang District, and we would welcome further articles, of agricultural interest to the Territory, from other correspondents.

MEASURES FOR CONTROL OF COCO-NUT TREE-HOPPER (SEXAVA SPP.)

By John L. Froggatt, B.Sc., Entomologist.

Measures for the control of any pest must necessarily depend on its mode of living and propagating, and its general habits. In order to make the measures discussed readily understandable, it may be desirable to first give a very brief recapitulation of the life history and habits of the coco-nut tree-hopper (*Sexava spp.*).

The adults and nymphs live in the head of the palm, sheltering on the under-surface of the foliage and feeding principally at night. From about 6.30 p.m. the females crawl down the trunks to the ground (a few may volplane down) to deposit the eggs, which are laid singly just under the surface of the soil. The adults then re-ascend the palm by crawling up the trunk. The eggs take from 49 to 107 days to hatch (average 70 days); the young hoppers (nymphs) emerge mostly at night and ascend the palms within, at most, 24 hours after emergence. These pass through a series of "moults" (six for the male and seven for the female) occupying a period of 78–117 days for the male (average 92.4 days) and 90–124 days for the female (average 100.9 days). The adults mate after about two to three weeks and eggs are deposited about five to seven weeks after reaching the adult stage. Epiphytic growths on the trunks of palms are often favoured sites for egg deposition.

The early-stage nymphs are not the voracious feeders that the fifth to seventh instars and adults are.

In elaborating methods of control, for any insect pest, the economics of each case must of necessity be an all-important guide to measures recommended or undertaken.

During the depression period when copra was barely, if at all, paying expenses, only those lines of attack, requiring the minimum expenditure, warranted special attention. Foremost amongst these was—

Biological Control

or the use of other insects which prey on or pass their developmental stages within the body of some stage of the host.

Minute wasp parasites of the eggs were found on New Hanover in 1930, but failed to breed under laboratory conditions. This was later identified as *Doirania leefmansi.*

In 1933, the egg parasites, *Leefmansia bicolor* (*Encyrtidae*) and *Doirania leefmansi* (*Trichogrammatidae*) were introduced into the Manus District from Amboina. The former bred up freely in captivity, but colonies of the latter got weaker and weaker and finally were liberated on the chance that they might establish themselves in the field.

The egg parasites of *Sexava* known to occur in this Territory have been recorded in the *New Guinea Agricultural Gazette*, Volume 3, No. 2,

Parasite breeding over an extended period has shown that *Leefmansia bicolor var.* is very easily bred in captivity. *Doirania leefmansi* has proved difficult to breed in the field laboratory, yielding comparatively weak colonies. The *Mymarid sp.* although breeding freely in the field has failed to develop through even a single generation in the laboratory.

The results achieved in establishing *Leefmansia bicolor* have varied in different parts of the Territory. Within three months of starting regular liberations from the field laboratory, it has been recovered from the field; in some parts it has maintained the generations very successfully, and in others where this has not been so marked, other procedures are now being adopted to test out the influence of increased ground shade and windbreaks.

Biological control, where successful, although slow in attaining its object, calls for very little expenditure of either money or labour, in most cases.

Tanglefoot Bands.

Bands of tree tanglefoot around the trunks of the palms have been tested out, and with one preparation large numbers of first, and to a lesser extent, second stage nymphs have been "trapped", the bands remaining tacky for about four months. This might have economic possibilities in the early stages of an outbreak in a restricted locality, but is too expensive on a large scale.

Use of Insecticides.

With the greatly increased value of copra and the maintaining of a fair price, other methods warranted detailed study; foremost amongst these was the use of insecticides, which could be applied in either of two ways, spraying or dusting.

Spraying requires a large volume of soft water, and a high-power spraying outfit. In many parts, owing to the coraline nature of the soil, soft water is very difficult to obtain in quantity, quite apart from the cost of cartage of such. Salt water has been tested but has not proved satisfactory.

Dusting on the other hand requires no water, although requiring a power machine, but one much less expensive than a corresponding spray outfit.

During long leave in 1936, extensive inquiries were made by the writer, in England, and information obtained from the United States of America, on the latest types of dusting machines, and finally an English machine was selected, equipped with a four-stroke, six horse-power engine, which was ordered early in 1937.

Meanwhile laboratory cage trials were instituted with a number of insecticides, both arsenical and non-arsenical (derris and pyrethrum) to ascertain those which promised the best results in the field. Cages were made of copra-bed wire about 3 feet high and 2 feet in diameter, in which fresh coco-nut foliage was suspended and a number of *Sexava*, collected at night, was placed. The dust was then applied by means of a hand-dusting machine, and the number of deaths recorded over a period of three days. In each series, one cage was untreated, to act as a control.

The insecticides comprised both proprietary and experimental preparations supplied to the Entomologist by the manufacturers from England, Australia and America, for testing in connexion with this work.

The arsenicals comprised arsenate of lead (several different brands), calcium arsenate and Paris green.

The non-arsenicals comprised various preparations of derris (as pure powder, and total extractives, diluted with an inert filler) and pyrethrum; of this group both proprietary and experimental preparations were used.

The results with the former were very consistent; 5 per cent. of the insecticide (slaked lime being the dilutent) gave an average kill of 80 per cent. with arsenate of lead, 87 per cent. with calcium arsenate, and 90 per cent. with Paris green, deducting a common factor with the controls. On the other hand, the non-arsenicals gave very variable results, even with the same preparation, ranging from 48 per cent. to 59 per cent. under the same conditions.

At the date of writing, the power-dusting machine has not been received, but on receipt, field trials will be instituted with arsenate of lead and calcium arsenate; in these trials data on the quantity of insecticides per acre, time taken to dust a given area, number of treatments for control, &c., will be worked out.

Such a method of control would in no way interfere with the course of biological control, but would rather tend to supplement it.

Without the application of insecticides the following measures will have to be adopted :—

1. Lighting of fires to give a volume of hot smoke between the rows of palms, having a line of boys to collect and destroy the adults and nymphs coming down from the palm heads.

2. Collection of *Sexava* at night; the number of females collected at these times is greatly in excess of that of males, and prevention of deposition of numbers of eggs is thus brought about.

3. Collection of *Sexava* eggs.

4. Turning over the surface soil by hoes, &c.; in this way eggs are exposed to predators and are destroyed partly by dessication and partly by deep burying.

Poison Bait.

Paris green and bran baits have been tried both in the heads of the palms and on the ground. This method, although very successful with the ground-frequenting locusts, was of no value at all with these tree-frequenting species.

Other Suggestions.

These have included the use of flame-throwers, and aeroplanes. The former have proved themselves of great value on the swarms of young locusts on the ground, but the *Sexava* belong to a family that have totally different habits and do not swarm in this way. To use flame-throwers to destroy the eggs would require a considerable heating of the soil and probably result in damage to at least the roots of the palm close to the surface.

Aeroplanes.

Where there are very large compact areas of any one crop, aeroplanes have been reported to be successful for some insects. But again economics come into the question with copra, which is a comparatively small return per acre for any

costly measure of control. Moreover, the *Sexava* shelter on and feed from the lower surface of the foliage and can be reached more readily and cheaply from the ground than from the air.

Moreover, in the dusting trials it has been found that a high percentage of kill was obtained where the "hoppers" had fed on fresh foliage but had crawled over dusted cages and so got a very small amount of the poison on legs and antennae, which were cleaned through the mouth. Thus dusting from the ground will powder the insects as well as the foliage.

WEEVIL PESTS OF COCOA.

By John L. Froggatt, B.Sc., Entomologist.

Two species of weevils, or "snout beetles," have been bred from cocoa trees, one being a pest of economic importance.

Pantorhytes Plutus, Oberth.

The adult beetle is about three-quarters of an inch in length, head, thorax and hind third of elytra (wing covers) and under surface of body and legs, black; one medium green stripe and one lateral green stripe on each side of thorax, and black portion of elytra marked with green stripes or spots. The snout is short and thick.

The point of attack may be anywhere on the stem or branches, a fork in between branches being especially favoured, heavy gumming arising at every site of infestation.

The eggs are laid in the bark, apparently singly, for only one larva is found in each channel. The grubs tunnel along the soft, woody tissue just under the bark, which is ultimately killed over the site of infestation, leaving a ragged opening, and seriously affecting the branch attacked. As a general rule the channel is more or less straight, but especially in cases of attack in a fork the branch may be completely girdled and the centre of the fork bored into.

The adults feed on both the bark and leaves, but more on the former. A trial was made on one plantation of spraying young trees, on which the beetles were very prevalent, with arsenate of lead, and the manager reports that the pest has been very considerably reduced by this means.

A trial was also made with paradichlor-benzene introduced into the channels, but proved a failure in killing the grubs, the mass of gum apparently hindering sublimation of the chemical and preventing penetration of the fumes into the head of the channel.

Pantorhytes plutus, the green cocoa weevil, has been collected in several parts of the Territory, but has only been recorded as a pest on portions of New Britain.

Dipterous larvae are nearly always present in the gum, but are apparently only scavengers.

Orthorrhinus Patruelis, Pasc.

This weevil has been bred from a small green branch of a cocoa tree, but is apparently not numerous. The adult beetle is dark brown in colour, and about half an inch in length; the surface of the elytra is rough and the snout of moderate length.

ARTIFICIAL CONTROL OF INSECT PESTS.

By B. A. O'Connor, B.A., B.Sc.Ag., Assistant Entomologist.

In a previous article in this *Gazette*,* biological control of insect pests was dealt with, and it was stated that, where this method could be successfully employed, it was ideal. However, most insect pests can be controlled only partially, or not at all, by parasites, and in these cases, artificial methods must be used. These may be roughly classified under two heads, preventive and curative, though there is a good deal of overlapping. The former are of course to be preferred to the latter, other things being equal.

Preventive methods may be grouped as follows:—

(*a*) Quarantine.

(*b*) Cultural.

(*c*) Use of resistant strains.

(*d*) Repellents and lures.

(*a*) *Quarantine.*—The object of quarantine regulations is, of course, to keep out of a country or district pests which do not already exist there, and which, if introduced, would cause damage to property. Most countries in our day have stringent quarantine laws covering a large range of insect pests, and these laws are frequently administered in a drastic fashion. An example of the application of domestic quarantine in the United States of America will serve to show how severe is the legislation enacted to restrict the spread of an insect pest which is a great potential danger.

Several years ago, it was discovered that the Mediterranean fruit fly, a destructive pest mainly of stone fruits, had made its entry into the fruit-growing areas of Florida, despite quarantine laws designed to keep it out of the United States of America. A large staff, totalling 70 entomologists, was immediately sent to cope with the danger, supported by large numbers of workers and a huge vote of money from Congress. It was realized that should this insect spread throughout the huge fruit-growing areas of Florida, it would cause immense loss, as it had done in the Mediterranean countries and elsewhere, including Australia. Fifteen thousand acres of orchard and virgin land were quarantined, including all areas where there was any likelihood of the fly having spread, and in this area, every fruit, wild or cultivated, was destroyed, though only a very small proportion was fly-infested. These measures were apparently successful in combating the menace, and Florida thus holds the record of being the only country where the Mediterranean fruit fly has become established and has been wiped out.

There are various opinions as to the effectiveness of quarantine of imports from other countries, some well-informed observers contending that the money spent in policing the regulations is largely wasted, and that it would be better spent on a concentrated campaign to wipe out each pest after it had been introduced from abroad. This is a very doubtful contention, for such a policy would necessitate prompt information as to the occurrence of any such insect, information which might easily not be forthcoming until too late. It would seem that a country or State with few points of entry should have an excellent chance of keeping out unwelcome insect visitors, and there is always the second line of defence if the pest

* See *New Guinea Agricultural Gazette*, Vol. 4, No. 1, January, 1938, p. 13.

does manage to penetrate the outer barriers. Western Australia has had signal success in excluding the codlin moth, present in the other States of the Commonwealth. The import of pome fruits, which the codlin moth attacks, is forbidden, but on about a dozen occasions the moth has become established in the apple orchards of the south-west. Nevertheless, it has been invariably wiped out, thanks to a rigid system of orchard inspection and quarantine of affected areas. In no other country has this pest been controlled once it has made its entrance. Immunity from the ravages of the insect means many thousands of pounds annually to Western Australia, and pays over and over again for the cost of enforcing quarantine regulations.

(*b*) *Cultural Methods*.—In the control of many insect pests, it has been found that correct cultural practice, and in some cases, special cultural methods, can play a big part. Such activities as the cleaning up of trash and stubble, or the burning over of harvested areas, are common-places of good farming for many crops. In the case of the rhinoceros beetle, a local pest of coco-nut palms, similar action is taken. It has been found that the destruction of surplus decaying vegetable matter on a plantation checks the activities of this insect, destroying its favourite breeding grounds. Similarly, wheat crops sown on weedy ground in Australia are subject to plagues of certain species of cutworm, whereas this trouble is avoided by utilizing clean fallow for sowing the crop. There are many such instances, all indicating that correct methods of agriculture can do much to limit the increase of injurious insects.

Ploughing and cultivating are useful also in that they expose insects living in the ground to the weather, and to the attacks of birds and other natural enemies, and also sometimes make the condition of the soil unsuitable for the development of these insects. On the outer fringe of the farming areas in Western Australia, for instance, much trouble has been experienced from the plague locust. This insect lays its eggs in hard, bare patches of ground, and the abandonment of many farms during the depression period provided large areas of cleared land suitable for this purpose. Ring-barked paddocks which had not been ploughed were also favoured breeding grounds. The only way to forestall a plague of locusts is to plough up the ground where the eggs are laid, exposing them to the sun, wind and natural enemies. Similar action would, no doubt, be useful in the case of the coco-nut tree-hopper (*Sexava spp.*) in this country, were ploughing and cultivating practicable, and in line with the cultural practice generally adopted.

Manuring has also been used to counteract the ravages of insect pests, as for instance in the case of the shothole borer of the tea plant in Ceylon. This borer girdles the branches with its gallery, and they frequently break off, causing considerable loss. However, it has been found that by the application of certain manures, chiefly nitrogenous, the plants are made more robust, and the loss of branches is considerably reduced.

Another practice which is often resorted to is the planting of "trap crops". These are favoured food plants of the pest which it is feared will attack the main crop. The trap crops are planted around the commercial crop, and are sown earlier, so that they reach maturity more quickly. When they are heavily infested by the noxious insect, trap crop and pest are destroyed, and thus a large number of insects which would otherwise have attacked the main crop are diverted and killed.

(*c*) *Use of Resistant Strains.*—Much work has been done on the breeding of plants which will resist the attacks of insects, and some good results have been obtained. Various methods are employed, including continued selection of the most resistant plants in a succession of crops, cross-breeding of two different varieties, and grafting of prolific but susceptible varieties on to a resistant stock. For instance, the Northern Spy apple has been freely used as a stock on to which commercial varieties are grafted, the Northern Spy being resistant to the attack of woolly aphis, which feeds on the roots as well as the aerial portions of the tree. Similarly, resistant stocks have been employed against the vine louse, *Phylloxera vastatrix.* Little has been done in the breeding of resistant animals, but one of the recommendations of students of the sheep maggot fly problem in Australia is that an effort should be made to breed out the wrinkles in the neck of the merino. The rancid grease collecting inside these wrinkles stimulates the fly to deposit its eggs there, and makes a suitable environment for the maggots. The wrinkles are, of course, the result of a deliberate breeding policy designed to increase wool production.

(*d*) *Repellents.*—Repellents usually take the form of chemical substances obnoxious to the insect pest concerned, though occasionally a crop is surrounded by a belt of some other crop distasteful to the pest, thus preventing the latter from approaching the threatened plants. Such a system is used against certain species of army-worm (caterpillars which attack in mass formation) in Australia. A protective barrier of oats, which the caterpillars dislike, is grown round the crop of wheat, which would be destroyed in an amazingly short time if the army-worms could gain access to it. Chemical repellents are frequently used to protect stock against the attacks of such irritating insects as stable-flies, blow-flies and buffalo-flies. The repellent, which may be a preparation of tar oil or crank-case oil, is sprayed on the animal, and helps to give it relief from its annoying enemies. A common practice in Australia is the "jetting" of sheep, that is spraying an arsenical solution under strong pressure in and around the crutch of the animal, to ward off the attacks of the sheep maggot-flies. This is supposed to derive some repellent action from its checking of bacterial action in the grease and dirt which fouls the wool, but it of course has the important effect of killing newly-hatched maggots which attempt to feed in the wool.

Other repellents go hand in hand with the forecasting of insect outbreaks. Some very effective work has been done in forecasting, the basis of the scheme being close observation of meteorological and other factors which favour the multiplication of the pests. When these have been tabulated for a number of years, and correlated with the activities of a pest, it is sometimes possible to predict the advent of destructive hordes, and thus provide an opportunity for the timely employment of preventive measures. In Australia, much is hoped from this system in the control of apple thrips, a destructive pest which every now and then assumes plague proportions, and may cause the total loss of the apple crop of a whole district. It is proposed to use repellent sprays on the apple buds when an attack is predicted, and thus keep the thrips off sufficiently long to allow fruit to set.

Attractants, though working in a way diametrically opposite to that of the repellents, are designed to produce the same effect, that is to keep insect pests away from a threatened plant or animal. Trapping of fruit-flies and blow-flies is

carried out extensively in Australia, the principle being the same in each case. A lure is placed in a trap, from which the insect, once it has entered, is unable to escape. Decaying meat is used to attract the blowfly, and various aromatic substances for the fruit-fly. Baits, also, are laid for fruit-flies, consisting of molasses and water containing a small quantity of poison. The bait is sprayed here and there on the leaves of the fruit tree, and the flies which are attracted to it sup up the fluid and are killed.

A method of prevention which has been experimented with locally against *Sexava* is "banding", that is, applying a band of adhesive material, somewhat similar to tanglefoot, to the trunks of palms in an area affected by the tree-hopper. The tests were made in Manus, where the great majority of the eggs of the insect are laid in the ground, the object of the bands being to trap any young *Sexava* which attempted to ascend the trunks of the palms after hatching from the eggs. During a period of between four and five months, the average catch per palm amounted to over 600. It must be remembered that the experiments were carried out in a very badly affected area, where the numbers of *Sexava* were huge. If an area of palms were treated in the early stages of an outbreak, it is possible that the bands might effect successful control. Similar bands give good results in Australian orchards.

The methods of artificial control which may be classed as curative, consist of the poisoning of the insect pest by spraying, dusting, fumigation and dipping. Spraying and dusting of plants attacked by insects are by far the most common methods of pest control, and generally give good results. In some cases, of course, it is not economically possible to use these methods, because the value of the crop is not sufficient to pay for the plant and materials necessary. However, orchardists and truck-crop growers throughout the world use vast quantities of materials in regular spraying and dusting programmes, and though the cost is considerable, the outlay is repaid many times over by the increased yield of crops. In the eastern States of Australia, for instance, apple trees have to be sprayed several times annually, in order to reduce the ravages of the codlin moth. Spraying for some purposes may be slightly cheaper and more thorough than dusting, while the latter has the advantage of mobility of plant and speed of application.

Some of the materials used kill by being ingested by the insect with its food, and setting up internal poisoning. Others, the "contact" insecticides, asphyxiate the insects on to which they are sprayed, while a third type, such as extracts of derris root, kills in both ways. The type of spray or dust used depends mainly on the feeding habits of the insect concerned. Some orders of insects, such as the *Hemiptera* (bugs, aphids, &c.), feed by inserting a long proboscis into the tissues of their plant or animal host, and sucking up the juices. Other orders, such as the *Coleoptera* (beetles) chew their food, while the *Diptera* (flies) include those which sup up surface fluids, as well as sucking species. A poison spray applied to the surface of foliage is of no use against a sucking insect, as it obtains its food from inside the leaf, so in this case contact insecticides are used. Some of the best known of these are oils, nicotine, derris and resin and soda washes. For the chewing type of insect, internal poisons are used, and arsenical preparations predominate, though the desire to employ something less dangerous to man and the higher animals has encouraged the use of derris, and various fluorides and fluosilicates. Some inects can be killed by internal poisons even though they may not ingest these

with their food. Among such are cockroaches and our local coco-nut tree-hopper (*Sexava spp.*). These pests have a habit of cleaning themselves by passing their feet and antennae through their mouths, thus removing any adhering particles of dust. Hence, if a poison dust is projected on to them, they frequently absorb a lethal dose in this way. This method is frequently used against cockroaches, sodium fluoride, which is non-poisonous to humans, being freely dusted in cracks and crevices and other haunts of the 'roaches. As the insects pass through the dusted area, a number of particles adhere to them, which they clean off later with fatal results. With such a wary feeder as the cockroach, this method is probably superior to any other.

It is hoped that successful control of *Sexava* will be obtained by dusting affected palms, and in this connexion many laboratory experiments have been carried out to ascertain the lethal effect of various dusts. At present, it appears that calcium arsenate possesses the best combination of cheapness and efficiency, and it has been shown by experiment that it kills the tree-hopper through both the cleaning habits and the feeding of the pest.

The practice of dipping probably needs little description here, as most people know of the regular dips given to sheep and cattle to control lice and so-called tick in the former, and tick in the latter. These dips are arsenical preparations, and experience has proved them to be most effective, so much so that legislation compels their use

Finally, there is the widely used control measure of fumigation. This is commonly employed against the pests of stored products, such as grain weevils, dried fruit moth and numerous others, and is also a standard method of controlling household pests and the scale insects attacking citrus trees. For stored products, the commonly used fumigants are carbon bisulphide, chlorpicrin, and hydrocyanic acid gas, while the last-mentioned substance is employed for citrus tree fumigation and house fumigation practically to the exclusion of all others. Hydrocyanic acid is sold in the form of powder, which, on exposure to damp air, gives off the gas. Fumigation of citrus trees is carried out under special gas-proof tents, and is an operation calling for knowledge and care. It is done at night, so that the air will be damp and the heat of the day avoided, but dew must not be present on the leaves, otherwise the gas dissolves in the dew, causing severe burning of the foliage. Of recent years, vacuum fumigation has been increasingly used with stored products such as grain, where difficulty might be experienced in securing a thorough distribution of the gas throughout the bulk of the material. Where vacuum fumigation is used air is drawn out of the space to be fumigated, and the fumigant is then liberated, and is drawn into the most inaccessible spots by the partial vacuum created. This ensures that fumigation is thoroughly carried out.

LOCAL TIMBERS FOR PLANTATION BUILDINGS, AND NOTES ON NON-INDIGENOUS HARDWOODS.

By G. E. Bliss.

The exports of timber from this Territory have advanced rapidly in the last two years and now form a valuable addition to the territorial income. These exports, however, are all in the form of logs and the imports of milled building

timber are still considerable. During each of the last two financial years timber was imported to the value of over £11,000, and to this must be added the heavy cost of freight and handling. There is also a large quantity of furniture imported which might be made locally.

It seems possible that, as far as Rabaul and other main ports are concerned, it may always be cheaper to import timber; the obstacles to the establishment of saw-mills sufficiently large to cope with the demand are considerable. Two main drawbacks are—

Firstly, lack of pure stands. With the exception of small areas of kamerere in New Britain and the *araucaria* belts in the highlands, the New Guinea bush is very mixed forest, rarely containing as much as 10 per cent. of any one species.

Secondly, lack of virgin country. Nearly all the New Guinea bush has been and is being marred, from the timber-getter's point of view, by the shifting cultivation and wasteful methods of the kanaka. The native obtains such timber as he requires in the sapling stage; uneconomically and often, unfortunately, before it is old enough to bear seed and regenerate itself. Matured timber trees are useless to him and in making new clearings for food crops he rings these, with axe or fire, or fells them. He leaves, however, such trees as bear edible fruits and it is fortunate that these include such useful timber species as "Tun", "Talis", and "Lup". These methods, combined with the lighting of hunting fires, have, in the course of generations, greatly altered the rain-forests of the country and gradually converted a large portion of them into kunai land, maintained as such and further extended by seasonal burnings. The remaining forest land has also suffered radical alterations and now consists very largely of secondary growth interpersed with food-bearing trees; a type of country which is, as a rule, not very suitable for the large-scale saw-miller.

It is, however, a type of country which is generally capable of providing ample supplies for the limited needs of a plantation and this article is written in the hope of assisting those planters who may be interested in producing their own timber. Many planters already do so; there are several plantations in this Territory on which all the buildings have been constructed from native woods. But there are also many plantations, surrounded by suitable bush, where all building material has been imported.

Owners and managers of such plantations may have been influenced by the theory that the cost of the necessary equipment would render local production uneconomic. Extensive and expensive machinery is not necessary for milling on a small scale. Logs can be pit-sawn where felled into slabs up to 6 or 7 inches in thickness and brought in by road or water to a small plant consisting of a 24-in. circular saw bench, a power planer and a heavy duty oil engine of about 3 b.h.p. Total landed cost of such equipment should not exceed £150.

The cost of building timber on plantations is generally allotted under two heads, viz., construction and maintenance, the latter including minor alterations and improvements. The writer, who admits to a lack of building and costing knowledge, estimates the first as averaging well over £1,000; and the second at about £100 per annum. The latter item alone, if approximately correct, should warrant an attempt at local production.

The following include some of the more common timber trees of the Territory: many of these are now being exported to Australia for the manufacture of plywood and veneers. Some of them are too small to interest the exporters but are

nevertheless, sufficiently large for plantation requirements. Their pidgin names are given, where possible, as a means of identification.

Intsia (Afzelia) bijuga—" Kwila ".—This timber is too well known to need description. Makes an excellent, though heavy, furniture wood.

Pometia pinnata—" Towan " or " Tun ".—Another well-known timber, not quite as hard and durable as " Kwila ", but easier to work. Rots quickly in the ground unless well tarred.

Eucalyptus naudiniana—" Kamerere ".—Grows only in New Britain, but is worthy of introduction to other parts of the Territory. It, and *Eucalptus deglupta* (which occurs in the Celebes and the Philippines and is held by some botanists to be identical with the local species), are the only eucalypts which thrive at sea-level in the tropics.

Calophyllum inophyllum.—Common on nearly all the beaches of the Territory; unfortunately, its habit of growth makes it difficult to secure timber of any length. It is a very popular boat-building timber in Malaya.

Vitex cofassus—" A sang " or " Sang ".—A hard, straight-grained, brown timber with yellow sapwood; has been described as " New Guinea Teak ".

Dracontomelon spp.—" Lup ".—Large, heavily buttressed trees with edible fruits. Yield fair wood.

Albizzia spp.—" Poun-poun ".—Several of the indigenous *Albizzias* yield good hardwood; the commonest, *Albizzia procera*, is generally found among and in competition with kunai (*Imperata cylindrica*) and should be very useful in re-afforesting kunai land. It is rather small for a milling timber but makes good round posts which last well in the ground.

Hibiscus tiliaceus—" Mungas ".—A small tree which is readily recognizable by its hibiscus type of flower which is yellow with a reddish-purple centre. It is generally found, like *Calophyllum*, on or near beaches and has much the same gnarled growth. The sapwood is perishable, but the purplish brown heartwood is tough and durable.

Canarium spp.—" Galip ".—Yield a moderately hard wood which, however, seems very liable to insect attack and is not very durable. Moreover, the trees, being valued for their fruits, are not readily available. However, their long, straight boles supply good lengths of timber, which, suitably treated, should be useful for ceilings and inside work.

Octomeles sumatrana—" Erima ".—A large tree with a long, buttressed bole. Provides a rather soft, light wood, nicely grained and suitable for all interior work.

Glochidion sp.—There is, apparently, no pidgin name for this tree; it may be recognized by a furrowed, grey bark and a small fruit which contains a number of red, wedge-shaped seeds attached to a central core. Yields a hard, tough, reddish timber.

Terminalia catappa (and other *Terminalia spp.*)—" Talis ".—These are common throughout the Territory and are conspicuous for the autumn-tinting of their foliage just before leaf fall. They yield a good, durable timber, elastic and easily worked, but since they also bear an edible nut it is, as in the case of Galips, difficult to purchase the trees from natives.

Heritiera littoralis.—Has been called "Looking Glass Tree" and is recognizable by the reflecting sheen on the lower side of the leaves. Generally found on or near beaches and yields a tough, hard, dark-brown timber; unfortunately, the tree is often gnarled and low branching.

Alstonia spp.—"Ai-ting".—This genus, which may be distinguished by its panicles of white, scented flowers and the latex which can be obtained from leaves and bark, is represented by three (possibly more) species in New Guinea. One, *Alstonia scholaris,* yields a soft wood which is not recommended for anything but case-making, but there is another species, possibly *Alstonia longissima,* which yields a hard, very durable, cream-coloured wood.

Pterocarpus indicus.—This is one of the best of the New Guinea hardwoods: other species of this genus yield "Padauk" which is exported in large quantities from Burma and the Andaman Islands. The local species is a large tree with yellow flowers borne on axillary racemes and the fruit is a round, single seeded, winged pod. The timber varies from pale yellow to red, and is considerably lighter than "Kwila" or "Tun". Makes an excellent furniture wood. Has no pidgin name, but the following local names may assist in its identification:—E-Yob (Gasmata), Sae Lupae (Aitape), Sarum (Wosika dialect of Karkar, Madang), Saiko (Nakanai), Tangi (Manam and Lower Ramu).

The above list is, of course, by no means complete. Different districts vary largely in their range of timbers available and local knowledge and the local natives will, no doubt, be able to suggest other trees worthy of trial.

Afforestation is generally, by reason of its long-delayed returns, a concern of companies and governments rather than individuals, but some planters may be interested in the planting up of non-indigenous hardwoods. The following notes are based, mainly, on observations of trees introduced to, and growing in, the Botanic Gardens, Rabaul. Most of the trees mentioned below are growing as specimen trees and have, therefore, larger girths than they might have attained in a timber plantation, although they have, however, been handicapped by the poor pumice soil of Rabaul. An asterisk (*) indicates that seed can be supplied.

Teak (*Tectona grandis**).—This is not really suited to the damp, non-seasonal climate of New Guinea, but the trees in the Botanic Gardens (now about 28 years old) flower and seed freely and have girths up to 7 ft. 9 in.

Mahogany (*Swietenia mahogani* and *Swietenia macrophylla**).—These are doing well. One of the latter, planted about 1910, has a girth of 6 ft. 5 in.; the former, planted ten years ago, girths up to 3 ft. 11 in.

East Indian Walnut (*Albizzia lebbek**).—This yields a good hardwood which has been used as a substitute for walnut. It is a quick grower and was planted in Rabaul as an avenue shade tree. Unfortunately, it has proved liable (as have many of the *Leguminosae*) to attack by fomes.

Trincomalee Wood (*Berrya cordifolia**).—Only one specimen of this is present in the gardens. It has a girth of 3 ft. 2 in. at eight years old.

Crabwood (*Carapa guianensis*).—This is also represented by a single specimen which has apparently suffered some damage in its early stages of growth. Planted in 1932, it now has a girth of 20 inches.

Spanish Cedar (*Cedrela odorata**).—This appears to flourish here; trees planted 28 years ago now show girths up to 7 ft. 4 in.

The above are timbers with an established commercial reputation. The following, which are not so well known, are all good hardwoods which have proved suited to local conditions:—

*Tamarindus indica** (Tamarind).
*Artocarpus integer** (Jakfruit).
*Adenanthera pavonina** (Bead Tree).
*Cassia fistula** (Indian Laburnum).
Filicium decipiens.
*Lagerstroemia flos-reginae** (Indian Lilac).
*Michelia champaca** (Champak).
*Myroxylon balsamum** (the source of Balsam of Tolu).
Pericopsis mooniana.

Dipterocarpus grandiflorus, which provides the "Apitong" which is imported into this Territory from the Philippines, has never been tried here, but should do well.

Trees planted for timber should be grown as far as possible under forest conditions. Specimen trees and trees planted in avenues may grow more quickly, but they generally branch too low and fail to form long straight boles.

KAMARERE (*EUC. DEGLUPTA* (*NAUDINIANA*)).

By C. E. Lane Poole, Inspector-General of Forests, Canberra.

In New Britain kamarere (*Euc. deglupta* (*naudiniana*)) occurs as a very fine riverine type thriving best in pure stands on the alluvium in a valley which is flat enough to be subject to annual flooding in the height of the rainy season which in New Guinea occurs in the north-west monsoon.

The species come under the category of a giant gum, for it towers to a height of 240 feet, and yields timber both in size and quality which rivals that of the great gums of Australia.

After the undergrowth has been removed, a stand of kamarere resembles in appearance the mountain ash forests of Victoria (Australia). The trees shed their bark in the same way, and, although the colour of the boles is darker—sometimes purplish—the species are very much alike.

The crowns of the kamarere, however, carry more spreading foliage, and the leaves do not hang down straight like the more sclerophyllous of the eucalyptus species, but spread out straightly. The leaves are, moreover, of less leathery texture.

The volume of timber yielded by the kamarere may be gathered from the following measurements of a tree felled some time ago for the Korindal Mill in New Britain:—

1. Log, 20 feet in girth, 8 feet long.
2. Log, 18¼ feet in girth, 16 feet long.
3. Log, 15 feet in girth, 18½ feet long.
4. Log, 14 feet in girth, 19½ feet long.
5. Log, 13 feet in girth, 18½ feet long.
6. Log, 12½ feet in girth, 29½ feet long.
7. Log, 11½ feet in girth, 18½ feet long.

The length of the eight logs into which the millable portion of the tree was cut measured 136½ feet, and the solid content of the logs was calculated at 2,120 cubic feet or 25,449 superficial feet. The volume of timber recovered after milling these particular logs is not known, but, owing to defects, it would probably not exceed one-third of the total.

A survey was made of an area of 14 acres which was chosen as being a patch of timber that could be taken as fairly representative of the timber lands at Korindal in New Britain. Other species besides kamarere were on the area, and details of measurements were taken of these trees as well. The table set out below gives an excellent idea of the volume of kamarere timber yield on the area :—

Species.	Cubic Contents.				Percentage.		
	Number of trees.	Total.	Per tree.	Per acre.	Trees.	Cubic feet.	Trees to acre.
Eucalyptus naudiniana ..	103	185,408	1,800	13,243	85.8	98.6	7.5
Pometia pinnata ..	5	646	129	46	4.2	0.13	0.3
Dracontomelum mangiferum	10	1,716	171	122	8.3	0.9	0.7
Celtis sp.	1	202	202	14	0.85	0.1	0.07
Vitex cofassus	1	210	210	15	0.85	0.1	0.07
Total	120	188,182	..	..	..	..	..

Realizing that it was possible that the species would succeed equally well in other countries, seed was obtained and despatched to many different places, including India, Africa, West Indies, Federated Malay States, Philippine Islands, Palestine, British Honduras and Mauritius.

While many failures were experienced, results in many places have been such as to show that the species is likely to become established and prove an equally valuable timber tree in its new setting as in its native habitat. A tree planted out as a seedling at Port of Spain, Trinidad, British West Indies, in 1928, when measured in November, 1936, eight years later, had attained a height of 65 feet and a girth of 3 ft. 10 in., whilst another planted the same year was of about the same height, but with a girth of 4 ft. 9 in. Others planted at the same time were 55 feet (24-in. girth) and 50 feet high (19-in. girth). Seedlings planted out in 1935 were 6 feet to 8 feet at the end of the first twelve months.

At Burma, India, trees reached a height of 17 ft. 6 in. in twelve months.

The Forest Research Institute of Kepong, Federated Malay States, reported that trees in eight years from planting out had attained girth measurements of up to 18½ inches.

Reports from Africa are equally encouraging. Seedlings planted out by the Forest Department at Uganda in 1934 a year later were 2 feet high, and, while one tree only gained 5 feet in height in the next twelve months, a companion tree added to its stature to the extent of 25 feet, due, no doubt, to the more favorable situation.

The Forest Department at Kenya has a tree which, at four years from planting out, was 30 feet high, and the trunk at breast height measured 17½ inches.

Many of the experimental plantings have been so highly successful that further supplies of seed will be distributed with a view to permitting further sowings to be made.

It is a matter of interest that it has been found that kamarere has successfully withstood 4 degrees of frost, and also that trees have succeeded on upland country as well as under riverine conditions.

METEOROLOGICAL DATA, KIETA.

By B. G. Challis.

The town of Kieta, situated 6° 13′ S., 155° 39′ E., on and in the hills about the western and southern shores of Kieta harbour on the east coast of Bougainville Island, is the principal administrative centre of the Kieta District. The harbour is extremely well sheltered from prevailing winds, especially in the north-west season, by the protecting nature of the surrounding country, which is extremely mountainous. These mountains extend to the north, west and south of the harbour and reach from 1,000 to 3,000 or more feet above sea level within five to ten miles from the town.

Above the 3,000-ft. altitude, about six miles from the sea, rain falls almost every day and mists and fogs are common, while at lower altitudes nearer the sea the rainfall is not so heavy but is more or less seasonal. In Kieta itself the force of winds is greatly reduced by the high mountains surrounding the harbour, and consequently the temperature there is hotter than in more exposed localities; and for the same reason the rainfall in the harbour is also affected. The average annual rainfall for the past 21 years is 119.19 inches.

Sea-planes could descend on and ascend from the harbour safely, and there is a small privately-owned aerodrome just outside the southern boundary of the town.

The basic rocks round Kieta give rise to a stiff clay soil except on the sandy foreshores. In some cases, close to Kieta the foreshore is higher than the land at the base of the foothills where water tends to collect. The country rock comes close to the surface and there is a good deal of erosion as for example in Toberoi some six miles away. The surrounding gullies contain talus materials which have fallen from the higher hills behind.

The Government Geologist, Mr. N. H. Fisher, M.Sc., reports as follows on the geology of this district:—

"The topography of the inland portion of Bougainville is exceedingly rugged. Mountains rise to a maximum height of 10,000 feet and in general the country consists of streams occupying steep-sided gorges between mountain ridges. In

many places, some near Kupei gold-field (six miles from Kieta), sharp peaks or knots occur with nearly vertical, bare rock faces. The mountainous country is bordered by a coastal flat usually a few miles wide on the north-east side of the island, while on the south-west, at Empress Augusta Bay, this coastal flat comprises an extremely large tract of country which is separated from the Moroni. Pumkuna area by a series of river gorges. In the upper reaches of the Kavarong, a reasonable extent of river flats and terraces are found. Climate at Kupei is generally warm in the morning, wet in the afternoon and cool at night . . .

At Kieta itself a tuffaceous conglomerate occurs in association with a porphyritic augite andesite."

The rainfall is high and evenly distributed throughout the year; there being practically no difference between wet and dry seasons. The north-west season is from October to February and the south-east season from March to September. The annual average relative humidity for 9 a.m., 3 p.m. and 9 p.m. readings is 79, 78 and 84 per cent. respectively.

Unfortunately, apart from the Government Station at Kieta, rainfall data is not available on the Island of Bougainville except at Hakau Coffee Estate some forty (40) miles north of Kieta, on the east coast.

The Department of Agriculture would welcome rainfall records from plantations prepared to furnish such meteorological records in this district.

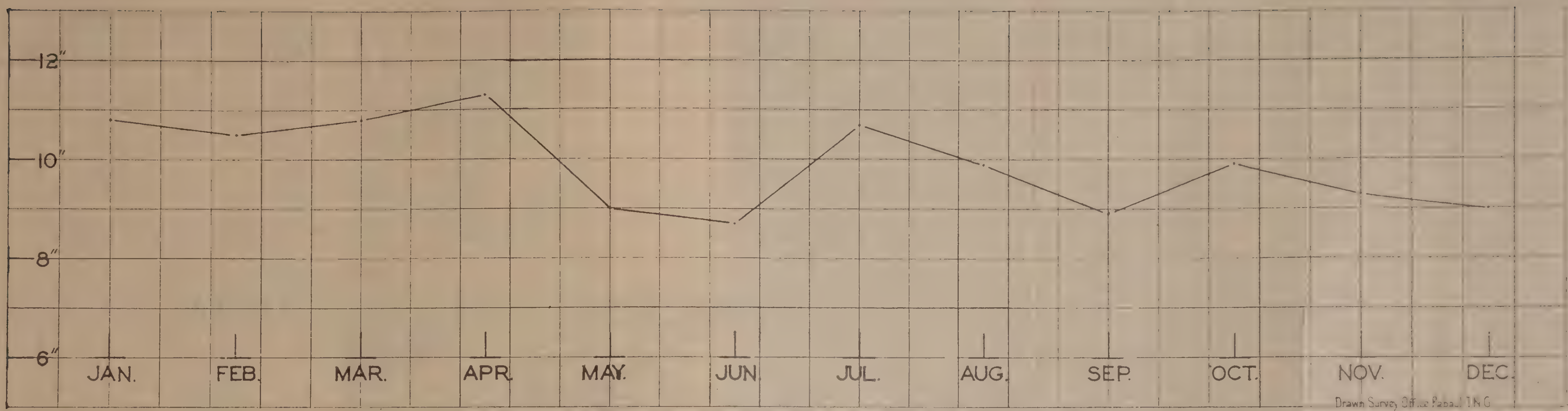
Rainfall records at Kieta and Hakau are set out in the following tables:—

MONTHLY AND YEARLY TOTALS OF RAINFALL AT KIETA DISTRICT (IN POINTS).

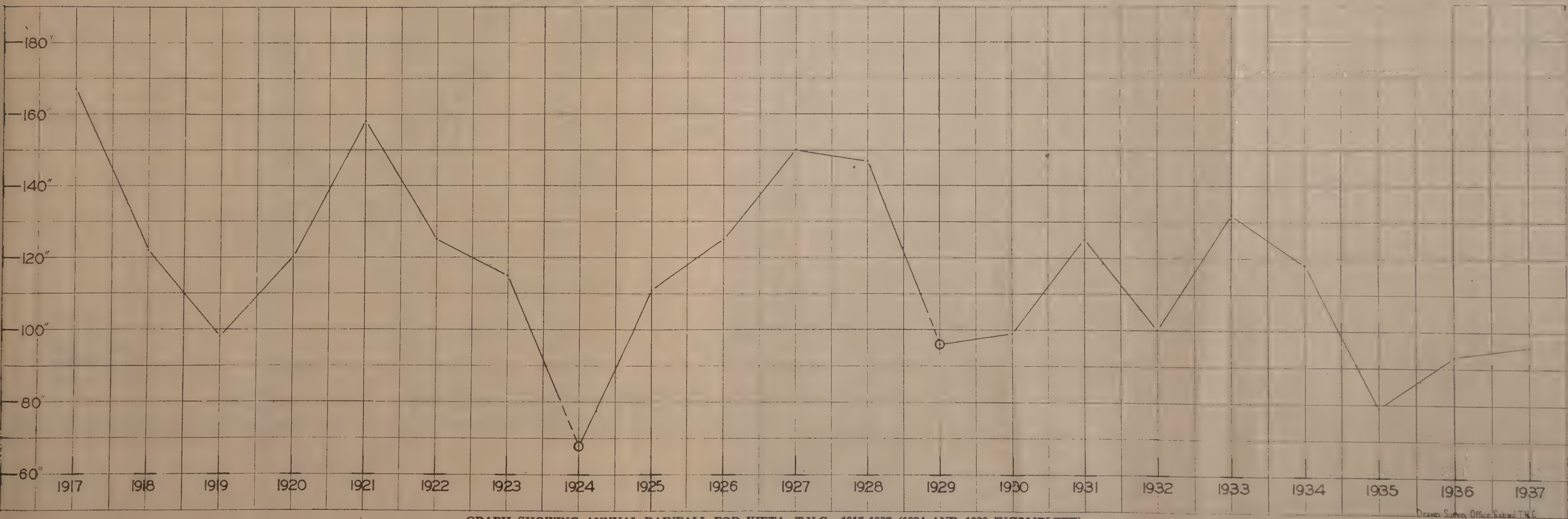
STATION—KIETA.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Yearly Total.
1917 ..	1,388	1,156	3,367	1,056	1,327	604	1,655	1,905	1,255	959	1,529	732	16,933
1918 ..	1,298	683	1,733	814	756	987	1,304	1,537	1,274	741	678	502	12,307
1919 ..	497	736	790	1,738	550	882	557	822	869	817	684	873	9,815
1920 ..	1,286	921	1,001	549	1,060	1,911	1,377	322	388	1,177	1,034	952	11,978
1921 ..	1,040	1,027	1,475	1,069	585	1,950	2,231	598	1,595	1,352	1,044	1,870	15,836
1922 ..	1,557	1,157	885	2,161	730	1,214	517	194	884	1,125	980	1,124	12,528
1923 ..	849	825	1,148	723	1,513	1,431	696	830	759	652	1,144	967	11,537
1924 ..	1,656	553	*	*	202	249	489	1,087	1,766	872	*	*	*6,874
1925 ..	479	603	1,352	2,243	698	980	519	2,029	914	776	710	133	11,436
1926 ..	902	558	388	1,434	1,128	447	1,278	1,716	1,134	1,007	1,212	1,265	12,469
1927 ..	1,952	3,602	1,019	1,350	1,345	644	919	804	628	718	850	1,217	15,048
1928 ..	515	2,134	1,051	1,196	1,482	413	1,533	940	824	2,701	1,287	619	14,695
1929 ..	769	*	862	811	675	587	707	1,603	1,302	1,102	632	525	*9,575
1930 ..	1,149	717	430	773	1,350	666	1,129	835	605	970	260	1,034	9.918
1931 ..	1,540	818	1,101	1,205	929	1,044	858	540	1,209	663	1,554	1,002	12,463
1932 ..	946	1,196	683	647	994	388	912	1,038	678	411	502	1,602	9,997
1933 ..	703	1,567	733	2,036	893	559	1,220	1,800	571	1,159	669	1,338	13,248
1934 ..	1,941	842	878	905	450	1,202	1,533	1,148	524	871	487	1,000	11,781
1935 ..	563	995	865	726	1,020	394	502	219	165	903	1,165	357	7,874
1936 ..	873	722	743	393	406	1,100	900	504	407	1,278	1,569	413	9,308
1937 ..	771	279	1,161	783	836	737	1,741	385	1,003	623	715	538	9.572
Average	10.80	10.55	10.83	11.31	9.01	8.76	10.75	9.93	8.93	9.94	9.35	9.03	119.19 inches

* 1924 and 1929 incomplete.



GRAPH SHOWING MONTHLY AVERAGES RAINFALL 1917-1937 (21 YEARS) FOR KIETA, T.N.G.



GRAPH SHOWING ANNUAL RAINFALL FOR KIETA, T.N.G., 1917-1937 (1924 AND 1929 INCOMPLETE).

RAINFALL MAP OF TERRITORY OF NEW GUINEA

METEOROLOGICAL RECORDS.

Hakau Coffee Estate (40 Miles from Kieta).

Month.	1937.		Rainfalls.		Wet days.	
	Rainfall.	Wet days.	Period.	Average.	Period.	Average.
January ..	10.68	15	2 years	11.75	2 years	17
February ..	4.41	12	2 years	18.43	2 years	16
March ..	9.58	18	2 years	13.53	2 years	19
April ..	10.21	12	2 years	8.49	2 years	9.5
May ..	11.70	11	2 years	7.36	2 years	12.5
June ..	5.16	10	2 years	4.48	2 years	10
July ..	9.76	20	2 years	9.31	2 years	16.5
August ..	4.85	9	2 years	6.35	2 years	12.5
September ..	6.72	15	2 years	5.58	2 years	14.5
October ..	6.29	15	2 years	8.67	2 years	16
November ..	2.53	10	3 years	11.95	3 years	11.7
December ..	7.72	13	3 years	5.28	3 years	11

Average Annual Rainfall for 2 years, 1936 to 1937—111·18 inches.
Rainfall for 1937—89·61 inches.

TERRITORY OF NEW GUINEA.

Annual Rainfall.

District.	Number.	Locality.	Rainfall, 1937.	Years recorded.	Average.
SEPIK	1	Aitape ..	110.12	17	99.23
	2	Wewak ..	97.10	9	88.11
	3	Angoram ..	106.34	3	95.08
MADANG	1	Madang ..	119.16	20	140.11
	2	Kulili	136.71	3	143.60
	3	Urit-Kurum ..	134.41	13	115.07
	4	Ramu	75.47	4	77.56
MOROBE	1	Baiune ..	74.09	4	67.65
	2	Bulwa	63.88	3	60.20
	3	Bulolo	61.78	7	56.06
	4	Edie Creek ..	114.65	8	106.58
	5	Kaiyapit ..	93.87	10	85.15
	6	Otibanda ..	51.11	2	57.24
	7	Salamaua ..	187.55	..	..
	8	Sattleberg ..	188.76	13	176.55
NEW BRITAIN ..	1	Arawe	204.82	4	175.89
	2	Gasmata ..	267.73	20	244.53
	3	Keravat ..	103.29	8	104.74
	4	Kokopo ..	65.41	11	83.10
	5	Kolai	225.04	5	209.50
	6	Lindenhafen ..	308.60	18	225.75
	7	Notre-Mal ..	158.07	9	164.46
	8	Palmalmal ..	200.62	6	205.37
	9	Pondo	199.93	11	176.58
	10	Rabaul ..	98.90	24	88.75
	11	Rapopo ..	74.46	5	80.12
	12	Ring-Ring ..	337.72	3	297.76
	13	Sum-Sum ..	200.95	5	146.32
	14	Talasea ..	200.40	20	172.24
	15	Tobera ..	83.50	7	81.07
	16	Watnabara ..	135.38	14	121.77
NEW IRELAND ..	1	Kalili	227.18	14	192.44
	2	Kavieng ..	116.04	21	120.34
	3	Katu	142.03	2	151.34
	4	Matandeduk ..	123.83	2	111.93
	5	Namatanai ..	143.43	20	136.90
KIETA	1	Hakau	89.61	2	111.18
	2	Kieta	95.72	21	119.19
	*3	Rugen	113.34	5	102.47
MANUS	1	Lorengau ..	143.19	20	150.60
	2	Pelleluhn ..	89.68	8	120.49

* = 1936. (Figures for 1937 incomplete.)

(*See* accompanying map.)

COCO-NUT IMPROVEMENT BY SEED SELECTION AND PLANT BREEDING.

By R. E. P. Dwyer, B.Sc. Agr., H.D.A., H.D.D.

Introduction.

This phase of coco-nut culture has received but scant attention in New Guinea, despite its being an important consideration, in increasing the yield of any crop. This is not remarkable, however, when it is considered how little has been done with coco-nut breeding and seed selection throughout the world, especially when the relative importance of this industry is taken into account and when older countries, which are much better financially equipped, have made rather disappointing progress with similar work.

The economic importance of coco-nuts to the welfare of New Guinea has been stressed and discussed at length in a previous article[15] where it was shown that copra is pre-eminently the most important agricultural product in this country. Thus any means of increasing their production or reducing cost of production, are worthy of the greatest attention. There are relatively few plantations in this Territory even amongst the newer areas which are derived from selected coco-nuts, though, where it has been done, even by rough methods of mass-selection, the improvement in the bearing areas can be clearly seen. It is not comprehensible why a fundamental and, usually, cheap and easy method of improving plantations, for all time, has been neglected. This is more notable when it is recognized that once a coco-nut area is planted, it may be in existence for more than 60 or 70 years. Once a planting of coco-nuts is carried out it is permanent and a very important fact is that poor seed cannot be replaced the following year, as is done with annual crops. The orchardist or farmer in temperate countries would rarely dream of utilizing inferior planting material. The same now may be said of the majority of rubber, cacao and coffee planters in tropical countries. The methods of selection used here would be ruinous with almost any other planting industry where the competition is greater. It may be pointed out that the coco-nut planter has fared better than would be expected considering the lack of attention given to original plantings. It is also doubtful whether the neglect of such a fundamental principle as seed selection would allow of success with most other crops, when the money and time invested are taken into account. There is the excuse that individuals developing in a new country, with small capital, require to commence their plantations as quickly as possible, so as to get early returns at small cost.

It is the intention of this article to emphasize the necessity for coco-nut seed selection, wherever new plantings are intended in this country. The advisability of long-term coco-nut breeding and investigations on pollination, nut-setting and other factors affecting yield are also indicated.

In all fairness it is pointed out that a proportion of the local planters have regularly practised seed selection and are quite cognizant of the need for care and attention in this direction, which is amply repaid by enhanced yields in the bearing plantation. A review of the work which has been carried out in other parts of the tropics in relation to selection and breeding of coco-nuts as well as its application to local conditions is presented. It is regrettable that so little local experience and

research on this very important subject is available, and it is considered that the subject as it affects New Guinea planters, as well as any plan of future investigations, should be reviewed.

The methods of practical seed selection, floral biology and so on are intimately associated with controlled methods of plant breeding, but the two subjects are discussed separately for convenience of exposition.

Factors Associated with Yield.

The factors associated with the yield of any crop may be briefly outlined with advantage.

Ecological and environmental conditions interact with the inherent characters in determining the growth and yield of any plant. The potentialities for yield are very largely determined by the genetical constitution of the plant, but it is often difficult to determine yield capabilities owing to the masking action of environmental factors. A tree of superior genetical constitution may be growing under very unfavorable circumstances and yield poorly whilst a comparatively weak type of tree may, under exceptionally favorable conditions, out-yield the former. It is known through the laws of chance and probability that, where numbers of individuals from a large population are considered and where selection is being made for high yield, the chances of this occurring are largely obviated with the bulk of the individuals under observation.

When the intending planter considers the commencement of a new plantation as a business venture, he should realize that the final yield, and thus the eventual income, will be controlled by the following main factors and all of the subsidiary conditions associated with them:—

1. Genetical and inherent characteristics of the trees or palms.
2. Environment.
    - 2A. Climatic environment, such as rainfall, temperature, altitude and prevailing winds.
    - 2B. Soil environment, e.g., chemical, physical and biological characteristics.
    - 2C. Cultural environment, e.g., manuring, cover cropping and cultivation.
3. Outside biological factors, such as pests and diseases, also changes and effects produced by other flora and fauna present.

It is hardly necessary to indicate that the incidence and effect of these factors are all closely inter-related with each other and with the ultimate growth of the plant.

The efficiency of the labour, management and harvesting methods may all have their effect and are probably best classified under the heading "cultural environment". The net returns from the crop are, however, determined by many factors which it is not intended to discuss here, but reference may be made to the previous article already mentioned (*loc. cit.*). The uses to which the products are put, supply and demand, competition with other products, freighting difficulties and other charges may, however, be mentioned as largely affecting market price.

The original climatic and soil conditions are usually difficult to change once a choice of site is made except by application of cultural methods, such as manuring control of natural erosion, &c.

The study of biological factors comprises several subjects such as entomology and plant pathology. Such factors are usually subject to artificial methods of control.

The genetical and inherent factors provide the subject of this article as being the most important determinant for yield capacity, especially when the environment is optimum. It may be stated, in other words, that the limits of the yield capabilities of any coco-nut plantation are determined by the hereditary constitution of the individuals which comprise the population on that plantation (regardless of however optimum the environment may be). As mentioned later in this article the largest proportion of such a population are hereditarily uneconomic, hence the aim should be to eliminate undesirable poor yielding palms and retain as great a proportion of high producers in a plantation as possible. This can only be achieved by methods of seed selection or by controlled methods of crop improvement. The advisability of investigating what methods of improvement are available can therefore be strongly advocated.

Effect of Environment on Growth Characteristics of Coco-nut Palms.

For more detail on this subject, the reader is referred to sections of an article on coco-nut disease by the present author[16] in volume 3, number 1 of the *New Guinea Agricultural Gazette* (pages 50-57) describing the relation of soil conditions to disease occurrence; also on "tapering stem" associated with soil erosion (page 52) and on "Deficiency Diseases," where a description of old palms growing on the soil-exhausted areas of New Guinea is given. It is pointed out that in the western islands the soils are usually rather shallow and light, being of coral derivation. Here the palms mature early and prosper for some years, but gradually go off as the soil conditions become exhausted. The stems taper and leaves gradually become smaller and fewer. On parts of these islands, it takes over 13,000 nuts to produce a ton of copra, while on parts of the Madang District, on the mainland, and on Dampier Island, in some areas just over 4,000 nuts are required to produce the same amount of copra.

There is a tendency for copra on soil-exhausted areas to become much thinner (also *see* article on diseases (*loc. cit.*)). It is known that the drain on manurial constituents by a heavily producing palm is very considerable, and when that has taken place over a series of years such effects are sure to influence adversely the growth characteristics of the palms and to mask the most favorable hereditary characters. The actual age at which palms naturally commence to decline is not accurately known as it appears to vary greatly according to soil and other conditions. In Samoa, Hamilton and Grange[25] have the opinion that palms there which are over 60-70 years old have declined more through old age than actual soil exhaustion. This does not appear to be the case with most areas in New Guinea, as chlorosis due to soil exhaustion may become apparent here in palms not half the age indicated. The older areas, however, are definitely the most affected, hence the inter-relation of both old-age and soil exhaustion to the decline of bearing areas must be considered.

Fernando in 1930[18] mentions a case where he planted over 100 acres in one area and over 500 acres in another area with nuts from two localities. One locality was characterised by palms with an open crown, the other carried trees with a full crown. Apparently these were environmental characteristics and no

inheritance of such characters occurred. It appeared from this that there is no object in selecting a palm which was good just because it was growing on good ground.

Since the publication of the article[16] previously referred to it has been observed that palms growing in the Bainings District of New Britain appear quite different from those of similar type growing near Rabaul, in the same island. There the water table is close to the surface, a condition which would lead to rather shallow rooting, the fronds are decidedly more feathery and open than is the case with similar palms elsewhere. There is also a decided tendency for the spathes to hang on most of the palms until long after the whole spathe and the mature nuts are due to fall. Owing to this environment those hanging spathes are decidedly pendulous on the majority of palms and commence to hang down beneath the petioles or leaf stalks as soon as the nuts reach a certain age and weight. These nuts do not fall as would be expected in most other localities. The nuts also tend to run small but usually possess a good thick kernel. In many places in the locality, during the wet season, the water table reaches the surface, but moves fairly quickly towards the sea owing to the rather pronounced gradient on the foreshore areas.

It is not proposed to describe the environmental effects on palm growth in detail, but rather to indicate that they must be taken into account when coco-nut selection is being carried out. The effect of manuring with the well-known manures, nitrogen, phosphoric acid and potash, as well as supplying rare metal deficienies, such as cobalt, zinc, magnesium and other elements on palm growth can only be considered as a separate subject, as is the provision of cultivation, cover-cropping and so on.

Nuts recently brought in from Agita Plantation, Matty Island, are said to take 15,000 to produce 1 ton of copra. The palms from which these nuts were produced are about 28 years old. There are said to be large numbers of native palms in this plantation which are considerably older. The native nuts in the village are also much smaller than elsewhere in the Territory.

PLATE I.—COCO-NUTS.

A—Unhusked. **B—Husked.**

Comparison of western islands nut (small) with young nut from same situation originally from Kar Kar Island.

Palms derived from seed nuts grown on Kar Kar (Dampier) Island were planted out in these western islands in 1930 and are now bearing. The nuts on these palms are much larger and better developed than any previously seen on the island even by the natives. This can be partly accounted for by the difference in age of the palms and by the fact that less soil exhaustion has occurred where the palms are not so old.

Most of the native palms on Matty Island always produce nuts in which the true kernel forms a very small proportion of the whole, as there is such a large amount of husk present. Though there are small nuts present, the greater proportion of the original island nuts are large enough in appearance, but are extremely light. When the entire nut is pierced with a knife it is seen that a small elliptical or ovate nut is present at the dorsal extremity of the nut and is attached to the stalk end by a thick, strong, fibrous rope of connective tissue. When the entire nut was cut through with an axe it was seen that in one case the depression occupied by the nut with shell attached was only $2\frac{1}{4}$ inches across. The size of the complete oval-shaped nut was 10 inches x 7 inches at the shoulders, sloping to only a couple of inches in diameter at the base, while the ridges were very prominent. The size of the nut within the husk was only $2\frac{1}{4}$ inches x 4 inches in length while the husk thickness varied from $2\frac{1}{2}$ inches in the centre to $3\frac{1}{2}$ inches at the diagonal end.

The small husked nut when split appeared almost solid inside as the central hole was only $1\frac{1}{8}$ inches across while the wet meat was at least $\frac{1}{2}$ inch in thickness. Thus meat thickness as a single measurement is very deceiving in this case, as despite the relative thickness, the cubic capacity filled by kernel was very small compared with the total size of the nut. It is very difficult to cut the copra from such nuts. A new nut borne by the young palms originally grown from Kar Kar seed nuts, was roughly comparable in outside measurements with the above, except that it was 1 inch shorter and not so ridgy. In this case the size of he husked nut was $5\frac{1}{2}$ inches by 6 inches which is almost a spheroid, and its cubic contents are nearly four times as much as the former small nut. The kernel was a little over $\frac{5}{8}$ inch thick, while the husk was only 1 inch thick in any part.

PLATE II.—COCO-NUTS.

Western islands (same as above) split to show differences in meat thickness.

The photographs give an interesting comparison of the two kinds of nuts. Undoubtedly the particular conditions on the islands have isolated, by a process of natural selection, a particular strain of nuts which resist the conditions. The soil is of residual coral derivation and in some places coral outcrops are seen. This soil is light in texture and contains scattered pieces of coral, shell and residual sand, while the humus layer is extremely shallow. There is a tidal swamp in the centre of the island. It is strange that this type of nut should produce so much husk, if soil exhaustion were the main cause of the reduction in size, as the husks are really the heaviest users of potash and some other manurial constituents. The introduction of new strains of nuts into this plantation was indicated as was the use of cover crops and methods of humus conservation.

There is, however, some evidence to show that even this apparently wide diversity in nut development may be mainly influenced by environment. P. Schmidt, the first planter to visit Kar Kar Island, stated to the author that "in the first plantings made there, 6,000 nuts were introduced from the western islands when they ran short of seed nuts." On the rich soil present there the western islands' nuts produced palms which were practically indistinguishable from the local types, which are noted all over New Guinea for their size and weight.

Variability.

The extreme variations and diversity of types present in any coco-nut plantation are well known to planters generally, as is the fact that individual palms show a wide range in fruiting ability. In this connexion, Jack and Sands in 1922[31] record from Malaya that the variation in the number of nuts produced per palm in Malaya was so great that 15.5 per cent. of the palms produce 24.5 per cent. of the crop and that 19 per cent. of the palms were uneconomic producers. Further, and what is of decided practical interest, they proved over a peroid of eight years (*see* Sharples[54]) that on the average, poor yielders and high yielders remain constant in this respect. In other words, on the average, good producing palms remain proportionately good yielders from year to year while poor yielders continue to produce poorly. Sharples[54] states that "no doubt the same constancy found in fruiting characteristics, also exists as regards the oil content of the copra within the range of seasonal variation; investigations are already in hand to prove this". Jack, 1930,[30] showed that on a good yielding plantation, yielding an average of 1510 lb. per acre, over eight years, an average of 59 nuts were produced per palm per annum, equal to 2,783 nuts per acre, per annum. The range, however, was from 5 to 115 nuts per palm per annum, over that period. He also stated that the average of 59 nuts per palm was some thirteen nuts better than the average for large estates in Malaya. The variable character, namely, number of nuts per palm per annum, showed a coefficient of variability of 34 per cent., compared with the mean under average estate conditions.

Smith, also of Malaya[56], in 1933 gave particulars of a very high yielding area as follows: "On a selected high yielding area of 80 acres carrying 3,875 palms only 17.8 per cent. bore 100 nuts or over. Thus the average of high grade palms in even a very high yielding area is very small and mass seed selection from such an area is unsound. Of the palms examined only 6 per cent gave 100 nuts of 500 grammes or more of wet meat and it is advised that 500 grammes is the lowest advisable standard for seed selection."

Sampson[52] stated the position in the following terms: "All coco-nuts are the products of cross-fertilization [this should be qualified.—*Author*], and, therefore, no palm has or can have a pedigree which would enable it to breed true to its female type. It is very largely on account of variation in the root habit and in the rate of new root production that there is such a difference in the bearing capacity of individual trees. Sixty nuts per annum is generally considered a fair average yield, yet every coco-nut grower knows that certain trees in his plantation will regularly produce more than double this number while other palms grown under identical conditions will not produce even half this average number".

In the case of tall palms cross-fertilization is believed to be general, thus not only are the palms under cultivation genetically impure and hence would not breed true to type, but knowledge of the seed nuts is limited to the mother or female palm. It is also an exaggeration to state that a very big proportion of palms in New Guinea plantations are hereditarily uneconomic producers. Variations in colour of nuts, such as green, yellow, reddish brown, are seen everywhere, as are variations in the size and shape of the palms, and of the fronds and nuts they produce.

Stockdale[60] in describing nineteen varieties of coco-nuts from a plantation in Ceylon mentions that the proportion of meat to kernel in one selection was 16 oz. meat to 16 oz. husk or a ratio of 1 : 1, while in another 12 oz. meat to 42 oz. husk, or a ratio of 1 : 3.5 was recorded. The above is only a brief introduction to the subject of variability present in coco-nuts, but many more variations are described under separate headings in this article.

Yield records over four years at Bandiruppuwa Estate, Lunuwila,[7] on a very uniform piece of land, confirm previous reports (from Ceylon and Malayan experiments) that high yield and low yield, both in number of bunches and number of nuts, are definite unalterable characteristics of the individual palm and fluctuate only slightly from year to year. More than twelve (12) bunches are usually produced in a year and there is a correlation between the number of nuts and number of bunches produced by a palm.

Selection of mother palms on the basis of high yield of bunches and nuts appears to be sound, without prejudice to the possible employment of controlled pollination later.

Professor Dash[12] in 1929 made statements concerning the position of coco-nut culture in British Guiana, which have some decided applications to the position in New Guinea. "Considerable expansion has taken place in the coco-nut industry of the Colony (British Guiana). Unfortunately after seeing a number of the coco-nut areas one is led to the general conclusion that the trees in most instances are not thriving. Many of these have been established on unsuitable soil with inadequate drainage and with scarcely any attention to cultivation. On light soils it is true that the trees are growing under conditions which enable them to resist cultural neglect remarkably well. For such trees to remain healthy and vigorous considerable expense is necessary for maintenance and cultivation, whereas normally on soils and under conditions suited to their growth, the palms fruit early and maintain productivity for a long period of years at a minimum expenditure for care and management.

A rough calculation obtained by equating copra and oil to nuts on the basis of (British Guiana), 1928 figures, indicates, after making necessary allowances, that the average yield per tree was hardly more than fifteen nuts. This is extremely low and supports the contention that all is not well with the industry agriculturally. Growers should not be satisfied until the average production per tree can be brought up to at least 50 nuts. This means that care will have to be exercised in the development of new areas and in the improvement of those already established. In the first place, I would urge greater attention to the question of selection of seed nuts, the main points concerning which are fairly well-known, but often not acted upon. Further selection is necessary in the nursery, young palms showing any signs of feebleness being rigidly rejected for transplanting. Then there is the question of giving young trees a good start. Apparently no one in this colony ever thinks that a coco-nut palm needs manure, and the proper time to commence to apply fertilizer is when the seedlings are transferred from the nursery to the field, which is a critical period in the life of the plant". Recommendations on manuring and tillage are then discussed.

Recent observations on five plantations in Zanzibar[2] for four years showed an average of 39.4 nuts per bearing palm, but in the fifth year a shrinkage to 31.7 nuts per palm was recorded. This shows considerable room for improvement by selection, if the yield is to approach the average for European plantations in Malaya, though the average is much better than that recorded by Dash (*loc. cit.*).

Methods of Seed Selection Commonly Employed in New Guinea.

In many instances no seed selection whatsoever is practised, and the seed nuts are bought as cheaply as possible. In some cases the precaution of purchasing seed nuts from an already good yielding plantation is taken, but this merely assures the perpetuation of average type coco-nuts. One has commonly observed the intending planter select germinated nuts ("Krus") which have been previously missed by the copra cutters. They are at such an advanced stage to be of little use for copra, and that accounts for their being utilized in planting, regardless of their shape, size, weight or yield of copra. Probably it is more common to select the seed nuts from heaps of fallen nuts gathered together for copra cutting, and in this instance good, round, heavy nuts are usually, but not always, selected. This type of selection is definitely better than none at all, because the chances are that good nuts would be obtained from good palms. The position is, however, comparable with barn selection in maize and other crops, as against seed selection in the field. The most progressive maize-grower, for instance, never selects his maize in the barn until he has first selected his plants and cobs in the field.

The great objection to selecting coco-nuts from a garnered heap is that one has no knowledge concerning the kinds and types of palms from which such nuts were derived. Palms may produce large nuts, because they are growing under particularly favorable conditions, and not because of any hereditary superiority. A poor-looking and weak palm may, in some instances, bear a very few, good shaped nuts, which would be selected from the heap, and thus perpetuated.

Typical examples of what occurs in new plantings were seen recently where the planters bought seed nuts from the neighbouring native groves and were prepared to buy any nuts the natives cared to sell them, because it was cheaper and handier in the first instance. Not the slightest attention was paid to what is one of the first precautions for successful coco-nut planting, namely, selection of good nuts. The excuses advanced for such neglect are centred around the time and cost involved, as well as the difficulty of obtaining sufficient selected nuts to plant up large areas. It is conceded that time and cost are involved—but it is a sound capital investment, which can only pay big returns in the future. A minority of planters here do observe the palms in the field, and then select heavy yielders of good type nuts from such individual palms.

In the planting of most native groves, very little conscious selection is practised, but their methods of close planting gives an enforced aid to natural selection, as it is usual for the stronger palms to survive. In certain districts of this Territory, the natives do select good seed nuts. They are well aware of a good type palm and only plant large, good shaped, heavy nuts.

A few of the most experienced planters here have marked individual palms on old plantations, and observed them singly for use as seed nuts, on new areas, which is a very commendable precaution. On one plantation in New Britain, where this was carried out, the coco-nuts are bearing very well. There are also better than average plantations where this has been done at Talasea, Gasmata, Bougainville, Kar Kar Island and Madang. A few instances of the methods used are given.

On one company plantation in Bougainville Island, the palms were derived from well selected old palms raised in proper nurseries. Later all weak and poorly growing palms were taken out and replaced, which procedure proved definitely beneficial.

Portion of a young plantation, which has just come into bearing, in the same island was planted with selected nuts, from old palms on another plantation which in turn were originally planted from selected nuts derived from the British Solomon Islands plantation. On appearance this area appeared to be better than the surrounding areas derived from ordinary unselected nuts.

One company recently planted up a large area in New Britain and selected a proportion of their seed nuts from old, heavily-bearing native coco-nut palms, which had been used for that purpose previously, and thus had been under observation for some time. In a new planting at Madang, a rather distinctive strain of palm with brick-red coloured nuts is being selected for seed nuts, as being a good type, as are palms carrying large nuts of the Markham type.

The owners of other plantations first allow the natives to select what they consider are good nuts. After being gathered into heaps these are then re-selected by the owner. Finally, after germination, all weak seedlings are thrown away. Some owners even go to the trouble of re-planting poorly-vigorous or chlorotic plants in the field. The weaknesses of this method all lie in the fact that nothing is known of the mother palms, as indicated previously. These, however, are all definite attempts to improve on present conditions.

Shape of Nuts.

Planters are mostly inclined to select round-shaped nuts, mainly because they are believed to be heavier in proportion to size. Elongated nuts are thought to have a bigger proportion of fibre at the ends, and, in some cases, this is undoubtedly true.

Work from Ceylon, the Philippine Islands and Malaya, seems to show that there is little practical difference in meat content between long or ovoid shaped nuts and round types, as either type may contain much or little meat. Some of the best copra-yielding nuts recorded have been long-shaped types. Further, red, yellow and green type nuts show more or less the same percentage of good and poor yielders, so that colour has little bearing on the yield.

As far as New Guinea is concerned it should be pointed out that the yellow type nuts are frequently associated with chlorophyll (green colouring matter) deficiency, though this is not necessarily the case. Genetically, chlorotic palms should be strictly avoided, though they may be useful for ornamentation. These yellow type nuts are common wherever coco-nuts are grown.

Maceda[40] compared the germination of 500 round nuts and 500 oblong nuts, and, twelve months after planting, it was found that round nuts germinated earlier than oblong nuts of equal volume, and also produced more roots, a greater number of leaves, and were heavier. Finally, both gave the same percentage germination. According to Copeland,[11] Walker made a very careful analytical study of brown nuts compared with green nuts, and this failed to show any constant difference whatever in yield of copra or in richness in oil, so there seems to be no practical object whatever in distinguishing between them.

In Guiana, it is said that a certain large orange-red variety is the best for planting, in view both of size and of yield of copra. A similar type of nut appears to flourish well on the mainland of New Guinea.

Methods of Seed Selection Advocated.

Jack,[29B] in 1929, stated that "there is ample opportunity for the improvement of the crop by the relatively simple process of elimination of uneconomic types, on developed estates, and by the selection of nuts from heavy bearers, for raising seed stock for new plantations." He further remarks that the term "section" as regards seed coco-nuts is mis-applied to a large extent, at present, because the methods of selecting them are far from scientific, and are rarely based on a thorough examination of the individual tree.

Thiele[61] and Staniforth-Smith[59] both stated that "seed nuts should be the product of healthy, heavily-bearing trees, not under twenty years old. Preference should be given to nearly round or oval shaped, medium sized with a thin husk, and they should be ripe, but not dry, while the three longitudinal ridges should not be too prominent."

Sampson[52] emphasizes the importance of selecting seed nuts from trees grown on land with similar soil conditions to those which are being planted up.

Copland[11] says, "select the seed of the palms which are conspicuously more productive than are their neighbours, which are growing under the same

conditions. Avoid those that have decided superiority of environment over their neighbours. Seed-nuts are chosen for their hereditary quality, and a good environment cannot be inherited."

The present author comments that this statement should not be carried too far, as it takes a favorable environment to give the best expression of the yield capabilities. It is well known, however, that palms growing on the edges of groves, around houses or manure heaps, should be best avoided as having undue advantage over their neighbours.

Smith[56] says "that the area chosen for the selection of seed nuts should contain a large number of palms yielding well above the average, when the chance of cross-fertilization with a high yielding parent will be probable; and a close examination should be made of individual palms which will at least ensure a good female stock. Only palms bearing 100 nuts or more should be selected as possible parents."

It is apparent that Sampson has stressed a very important point. Thus, where one is selecting coco-nuts for planting on the loose pumice soil, close to Rabaul, it is preferable to select them from palms which are doing well on a similar area. The same principle would apply when selecting for heavier soils, such as in the Bainings District, where it is feasible to believe that a different type of palm altogether might fare best. The standards as to a good producing palm could conceivably vary according to the conditions under which the selections are being made. It does not seem necessary to select from the best areas on the plantation only, because a palm which does well under relatively adverse conditions might be the most valuable seed parent.

It might be thought that this is a definite argument against introducing large nuts from islands, such as Kar Kar or Witu Island. This is not the case, because it is most probable that different strains of nuts are present here. If the palms growing on these islands are derived from different strains, and were also grown from selected nuts in the first instance, as is explained elsewhere, then it is a sound plan to use such sources as a basis for seed supply. If it is purely a matter of differences in environmental conditions, no good purpose can be served in introducing seed nuts to outside centres from such areas.

Planters here are generally of the opinion that they can only select from very old areas. This has a sound basis for recommendation, because in old areas the palms are necessarily long-lived and heavy yielders. In most cases the weaker and less vigorous palms have been weeded out, over the years. Nevertheless, although this precaution is desirable, it is not essential. In fact, selection from a relatively young estate known to be derived from previously selected nuts can be recommended where older areas are not available. It is widely believed that coco-nuts must reach a certain age before the young coco-nuts will germinate satisfactorily.

It appears from observations made in the *Kew Bulletin of Miscellaneous Information*[3] that the widely-held belief that the nuts from young trees should not be used and that plants should only be raised from fully-matured trees, was first based on a statement made by Simmons, 1877, in *Tropical Agriculture*.[55] The latter advocated selecting fully ripe nuts from fully-matured trees, and

amongst other statements said: "Those nuts which may be taken from trees of immature age will, if planted, rot away at the eye; and the plants, if any, be successfully reared on transplanting, will grow very rapidly, and acquire bulk, but the fruit will drop before the kernel acquires consistency, the root stalks break, and the trees entirely fail before mid age."

This idea seems to have been perpetuated by some periodicals and text-books, although Copeland[11] in his book lends no support to this contention, and there has been no experimental evidence to support it. Inquiries made from Kew could find neither direct confirmation, nor absolute refutation of the truth in this statement, but refer to it as follows: "On physiological grounds there would appear to be no justification for the statement as it stands, though no doubt it would be unwise, for more than one reason, to plant nuts from young trees in the first year or two of their coming into bearing. It is possible that it was based on a superstitious native belief or else the argument of a plantation owner who had trees of a particular age being offered for sale. In British Guiana it is advised by the Department to select nuts from good-bearing palms, which are neither very young nor very old.

In some islands in the Laccadives,[3] off the Malabar coast, it is stated that, where the soils are very poor, palms normally take fifteen to twenty years to come into full bearing. The natives there have regularly selected nuts from any good bearing palms present, which come into bearing at ten years, and they only select first-class early maturing material, with remarkable results.

Particulars are quoted in the *Kew Bulletin* (*loc. cit.*) of a coco-nut plantation in the Island of Nevis, West Indies, planted by a Mr. Crum-Ewing in 1907, where palms in their third year of bearing yielded perfectly sound and full-sized nuts (95–98 per cent. over 3⅞-in. gauge when husked) which, when used for seed, germinated freely and in a normal manner. It was stated that the original seed nuts used came from Jamaica, but in turn these came from San Blas, whence come the finest nuts in the Western Hemisphere. One thousand nuts, five years and three months old, when germinated for seed nuts, gave an 89 per cent. germination, seven months after placing in the nursery. It is recorded that one palm four years and four months old bore 40 nuts, which indicates the opportunities for selecting nuts for early maturity in an ordinary plantation. It was commented that the high percentage of good-sized nuts, borne on the young plantation at Nevis, afforded ample justification for the great trouble which was taken in selecting the original seed nuts in Jamaica and elsewhere. Crum-Ewing's statements are worth remarking, as he does not agree with Simmonds: "Nuts should be taken from trees whose good character is well marked. It appears that the pedigree of a coco-nut tree is of the utmost importance. It would be better to use parent palms showing similar characteristics to those for which the parents and grand-parents were selected, even if only one or two years' observations were available, than use old trees past middle age, of whose parentage there is no record."

It was mentioned that it would be better not to take seed nuts from palms until they were in their third or fourth year of bearing, mainly owing to the varying periods at which the nuts come into bearing. There is, however, probably

some truth in the statement that nuts from very young palms do not germinate properly as, for example, nuts which had fallen from young palms of the Markham Valley type at Keravat, did not germinate so freely at first, as they did later on. This was particularly the case with some individual young palms, and may be truer of certain strains.

It is not always possible for the planter to keep yield records of individual palms, but nearly every one who is familiar with his plantation knows of the existence of heavy yielding palms on the place. Many of these palms may be under casual observation for years. When such palms are found to be consistently high bearers, they should be distinctly marked either with tar or paint, or preferably numbered with a zinc or aluminium tag. These can then be observed more carefully as potential mother trees for future plantings. Planters are known here who have carried out the procedure outlined with good success. A few nuts from each selected palm should be examined closely for proportion of husk, thickness of kernel, &c. The thickness can often be determined without injuring the nuts at all, by just inserting a strong knife through it until the shell is touched.

The methods outlined are not ideal, as it would be necessary to maintain a cropping register for individual palms to obtain best results. Professional investigators would be obliged to keep detailed records on sheets or cards specially printed with suitable headings for that purpose. It would be a sound idea for some of the larger organizations here to keep similar records on selected areas of, say, about 50 acres in extent. Even a register of this nature would not be a sure index of the copra-producing ability of the palms, as there are many factors to consider. Still, it would afford a reliable indication for selecting good palms. Particulars of how to keep a cropping register are available from several sources, and it is not proposed to discuss them here. To indicate just how valuable accurate records and measurements are, Smith[56] says that an increase in meat thickness of 1 mm. between two nuts with kernels 12.5 and 13.5 mm. thickness respectively meant a difference of no less than 8 per cent. in the copra yield, and that it it almost impossible to detect this difference by eye alone.

Pieris, in Ceylon,[48] has listed several useful criteria which indicate a good palm on appearance. He and several other investigators have indicated, as far as possible, the correlation of external characteristics with that of yield of copra. Belgrave and Lambourne[5] (Malaya), in 1933, stated "that Cooke in 1932 had shown that there was a remarkable close correlation between the weight of husked nut and the meat content." Cooke,[9] in 1934, confirmed this finding, as did Pieris[47] working in Ceylon in 1934 and 1935.

For the purposes of the layman unity is taken as a complete correlation, and the latter showed in one large series of experiments that the correlation coefficient between weight of husked nuts and weight of copra was $+0.971$. This is almost exactly comparable with the findings in Malaya.

Cooke (1930-34), in Malaya,[9] used nuts in his determination which had been grown under a wide range of conditions to see whether there would be

a wide range of variability, and whether it was necessary to split the husked nuts to rule out possible variation due to the amount of water contained in each nut. The nuts were collected from estates 32 years old, 18 years old, and 17 years old, while nuts of mixed ripeness were collected from small holdings in the coastal areas of one district in Malaya. There was no very significant difference in the coefficient of correlation in nuts derived from various sources. He concluded that there is a high correlation between both unhusked nuts and meat, but especially between weight of husked nut and meat, and that the splitting of nuts is not essential in determining the yield of copra for all practical purposes.

Pieris,[47] of the Coco-nut Research Scheme, Ceylon, makes the following conclusion from his work: "Although there is a marked positive correlation between the number of nuts produced by a palm and the weight of copra manufactured from these nuts, the expression of yield by number of nuts is open to considerable error, although it is a very good rough estimate. The error introduced is due to the variability in the size of nuts from different palms, and more especially from different varieties of palms. Some varieties (or selections) produce small nuts, which although present in large numbers, may produce no more copra than a moderate number of larger nuts from other varieties. The correlation between weight of unhusked nuts and weight of copra is higher than that between weight of copra and the number of nuts. This ratio, however, tends to alter with progressive desiccation of the nut and the loss of water on storage in heaps. The third method of expressing yield is by making use of the weight of husked nut, and it is shown that this is the most satisfactory and least troublesome method of arriving at a reliable expression of yield. In this case, errors due to the variability in size of nut and to drying of the husk are avoided."

He also showed that with uniformly ripe nuts and average drying conditions the percentage ratio between weight of copra varied between 32 and 33 per cent., but that may be reduced as low as 30 per cent. where excessive drying was practised or the nuts were immature. It is not proposed to go into a scientific discussion on the subject, as Cook, Pieris and others have done this for the benefit of investigators in their particular countries, and there is practically no data to analyse as far as New Guinea is concerned. The practical utility of the findings quoted above is what counts from our point of view. It is most important to realize that it is not necessary actually to split the nuts and actually weigh the wet kernels or dry the copra to get a reliable expression of yield of individual palms. It is, therefore, a matter of great moment to find that the three characters, namely, number of nuts, weight of unhusked nuts, and weight of husked nuts, and especially the latter, are all positively correlated to a high degree with the weight of copra.

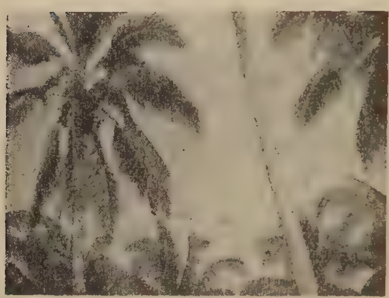
Pieris, in his article on seed selection,[48] has given the following criteria for the selection of mother palms, which are quoted verbatim:—

"A mother palm should be selected according to the following standards:—

I. The trunk should be straight and stout with leaf scars situated close to each other. Avoid very tall and curved trunks.

II. The fronds should be short and well-dispersed on the crown. The orientation of the fronds on the crown can be represented diagrammatically as follows: it will be noticed that there are three main types:—

PLATE III.—COCO-NUT PALM.



Type I. "Undesirable." Fronds unevenly distributed; lower fronds drooping.

PLATE V.—COCO-NUT PALM.

Type III. "Undesirable." Fronds distributed distally or in a semi-circular position.

PLATE IV.—COCO-NUT PALM.

Type II. "Desirable," good type. Fronds evenly distributed.

Types 1 and 3 should be avoided, even if they show other desirable characters. Type 2 displays the best spread of fronds.

III. The bunch stalks should be short and should not show any tendency to droop.

IV. The inflorescences should carry a fair number of female flowers or button nuts—up to 100. Avoid palms with inflorescences (flowering spathes) that are over-stocked with female flowers. They are not thrifty.

V. The crown should carry a large number of fronds and consequently a large number of inflorescences. Avoid crowns that look empty on one side, even though the inflorescences on the other side appear to set many nuts.

VI. It need hardly be said that inflorescences should be well stocked with nuts. But it might be mentioned that inflorescences in all stages should be noticeable on the palm carrying their full complement of developing nuts. Very often one is deceived by heavy lower bunches.

VII. The size of the nuts is not important provided large numbers are present. [Very small nuts should be omitted.—*Author.*]

VIII. The weight of the husked units should be high since on this depends the copra-producing power of the palm. The number of nuts and the weight of husked nuts provide the best standards of selection.

IX. Do not select palms growing in favorable situations, such as near cattle sheds and human dwellings, because they will be better than palms growing in the open field in competition with their neighbours, merely by reason of their favorable surroundings.

Palms that bear well in a normal or even unfavourable environment should be selected."

He also states "that at the end of three years all selections that have not produced on the average 100 nuts and 175 lb. of husked nuts, per annum, should be rejected. Wherever possible there should be at least one proved mother palm for every five acres on an estate."

Palms of hereditarily poor vigour are very liable to insect and fungous attack and are very susceptible to unfavorable soil conditions. There is no doubt that some palms show an hereditary tendency to chlorosis (chlorophyll deficiency). Such palms are readily apparent on even the best kept plantations, and should never be used for seed.

Sampson[52] and Hunter and Leake[28] have both indicated one potent cause of premature nut-fall. The weight of a well-developed bunch of nuts is considerable, and, if unsupported where the leaf stalks (petioles) are too long, the rachis (stalk) of the inflorescence will tend to buckle and twist. This causes constriction of the vessels which carry nutriment to the developing fruit, and leads to the fall of the immature nuts as the result of starvation. The natural support of the bunch is the leaf stalk, and a strong leaf stalk combined with a short inflorescence rachis forms the most important of the vegetative characters which are desirable.

Tangible Results to be Expected from Seed Selection.

The average palm in New Guinea plantations probably does not produce more than 40 nuts per palm per annum, and the average for all plantations may be less than that. One of the soil-exhausted areas in the Territory averages less than 30 nuts per palm per annum, an average plantation produces 40 to 50 nuts per palm per annum, while some of the best places in this country do not produce more than 60 to 70 nuts per bearing palm. In assessing the number of nuts per palm, it must be recognized that when numbers of nuts are the basis of comparison, the smaller size of the nuts on poor yielding plantations somewhat balances the smaller yield obtained under those conditions.

From certain islands of the Laccadives, Malabar Coast, particulars are given[3] of palms coming into bearing in ten years. These throw out a fruiting spike every month after that age is reached, bearing 15 to 20 nuts, and so yielding

180 to 250 nuts per year, and going on bearing at this rate until they are 60 years old. They often do go on bearing until they are 70 or 80 years old, and some are believed by the people to be more than a century old.

At Buitenzorg, Java, Mr. de Veer[13] has taken yield records on 46 selected palms derived from a number of different localities in that country. The lowest average yield per palm over that period, including the years when they were coming into bearing, was 84 nuts per palm, while that of the highest yielding palm was 178 nuts per palm over the same period. Thirty-three palms out of the 46 averaged over 100 nuts per palm over that period, while the average per palm for that period was 120 nuts. If palms capable of producing one-half to two-thirds of this total were used as planting material the increase in the bearing capabilities of plantations here would be very considerable, as simple calculations would show.

Jack,[30] Malaya, in the course of a lecture to producers gave the following figures and facts, which are very easy to follow. He said that "assuming the average palm to produce 60 nuts per annum (the actual average is lower) and that each nut produces 250 grammes of copra (a figure derived from actual weights, and 453.6 grammes = 1 lb.), then the average palm should yield approximately 33 lb. of copra annually, of course allowing for the limits of variation. [At this rate a palm producing 40 nuts should produce approximately 22 lb. copra per annum.—*Author.*]

"Owing to variability present it should be possible on new plantations to raise considerably the average yield per palm by the rigid selection of high yielding palms for the supply of seed nuts for future plantings. Seven of the 470 palms which were analysed for yield showed calculated yield values exceeding 50 lb. of copra per annum, while four of them even exceeded 65 lb. of copra per annum, so that the selection of palms as seed-bearers is not a difficult matter. A plantation planted entirely with palms capable of producing 50 lb. of copra per annum would be equivalent to an increased production per acre of approximately 50 per cent., and even this increase might conceivably be exceeded. While such an increase is possible under practical conditions, and considering the hybrid nature of many of the seed nuts, it is more likely that the first generation increase would be of the order 25–35 per cent., but even this increase would be highly desirable."

Smith[56] says "that with his standard scaled down to 100 nuts of 500 grammes of wet meat per palm only 6 per cent. of palms in a given area (high yielding) are for selection as mother palms." He also states that by selecting palms of this standard, yields of 20 piculs = 2,720 lb. per acre, should be attainable under favorable environmental conditions. It was indicated, however, that he had already recorded from a promiscuous seed supply the phenomenal high yield of 16 piculs, or over 1 ton 19 cwt., per acre (not hectare) for thirteen years over an area of 80 acres, the palms being 27 years old in 1933; this was equivalent to about 82 nuts per palm. This was, undoubtedly, due largely to environmental conditions, but said that it indicates that potentialities are greatly in excess of standards hitherto accepted as high, if close seed selection is carried out in an area of this yielding capacity."

This amount appears exceptionally high compared with what prevails under New Guinea conditions, but if an average acreage yield of the limits he indicates were harvested per hectare here, that would greatly increase the existing yields in this Territory. It would take controlled methods of plant breeding to get maximum increases in yield, yet a substantial increase may be expected from methods which are applicable on a commercial scale.

Hamilton and Grange[25] recently investigated conditions in Samoa on the New Zealand Reparation Estates. They advanced the following arguments in recommending seed selection there: "Visual observations of trees in the plantation suggest that they vary considerably both in productivity and habit of growth. Different types of nuts were collected at the Vailele plantation and measurements made on a ton of them—

> The transverse diameter of the nut varied from 2.7 inches to 4.5 inches, while the longitudinal measurement varied from 3.6 inches to 5.1 inches.
> Thickness of meat varied from .35 inch to .50 inch.
> Dry weight of copra produced varied from—79 to 209 grammes.

Since the best of the nine nuts recorded returned three times the amount of dry copra per nut that the poorest did, it appeared that there is considerable room for improvement in the type of nut which should be selected for future plantings. The opinion was fairly freely expressed, however, that any selection for the larger size nuts would lead to decrease in the number of nuts produced per tree, but work conducted by Smith in Malaya seems to lend no support to this contention, provided selection for size is kept within reasonable limits. Smith, writing in the *Malayan Agricultural Journal* for June, 1933,[56] gives details of the results of selection in that colony. An area of 80 acres, which had an average bearing record of 82 nuts per palm, or 19½ cwt. of copra per acre per annum, was selected, and the individual trees graded according to production with the following results:—

Total number of palms examined	3,975
Total producing 100 nuts and over	690 = 17.8 per cent.
Total producing 50 nuts and over	1,109 = 28.6 per cent.
Average of "100" nut palms	117.23 nuts.

Nuts from these selected trees were then taken, and the yield of wet copra per nut determined—

Net weight of copra per nut in grammes.	Number of nuts in class.	Percentage of nuts in class.
Over 700 grammes	3	0.4
600–700 grammes	47	6.8
500–600 grammes	191	27.7
400–500 grammes	307	44.5
300–400 grammes	128	18.6
Under 300 grammes ..	14	2.0

For the purposes of comparison with the weights given for yield of dry copra from Samoan nuts, the weights given in the above table should be halved. From data given by Smith it would appear abundantly evident that it is possible to find trees

which combine both large size of nuts and heavy yielding capacity, and there appears considerable scope for selection if further areas are to be planted in Samoa.

In a crop of this nature planting is done once and for all, and expense incurred in securing selected seed may be repaid manifold during the normal life of the crop. Initial lack of selection cannot be rectified as in the case of annual crops.

Some selection has been practised in the past on the basis of nut shape and size, but while this is of undoubted importance, it should be carried a stage further and the yielding capacity of the trees producing such nuts determined or results are likely to be disappointing. Even with careful selection phenomenal results should not be expected; if production can be increased by 10 per cent., the cost of selection would be amply repaid while the elimination of low producing or "boarder trees ' should materially assist to raise the average level of production ".

Stockdale[60] from measurements made on a large number of nuts stated as follows: "It appears but reasonable to expect that larger nuts would possess proportionately more kernel than smaller ones; but the figures obtained do not appear to bear this out, for it was found that the three best nuts examined in this respect were comparatively small besides some of those examined which yielded less kernel. The range in weight of kernel for nineteen types varied from 12 to 18 ounces, whereas that of the husk showed a wide range of from 16 to 48 ounces ". He mentioned that the husk takes up nine and a half times the amount of potash salts which is absorbed by the meat and over 100 times the amount of lime salts which the meat takes up. Thus it is obvious that the more fibrous type of nuts should be avoided as being uneconomic feeders.

According to de Veer[13] a very interesting practical demonstration of the value of selection was made in the East Indies. The Landbouw Instituut for purposes of comparison planted out 250 nuts from selected mother trees in various parts in both Java and Sumatra. The original nuts were collected and planted out in 1911, and the average yield of the palms from these selected palms over the last ten years (to 1934) was 120 nuts per palm compared with the average of 40 nuts per palm usually harvested on Java estates.

Govindu Kidavu[67] classified palms according to their bearing capacity on the basis of five years average yield records ending in 1927. He classified trees which yield up to 30 nuts per year as poor bearers, those which yield between 30 and 100 nuts as medium bearers and those which yield above 100 nuts per year, as heavy bearers. Over this period he recorded some palms as yielding an average of fourteen nuts per annum whilst others yielded an average of 121 nuts yearly.

It is as well to recognize when interpreting results that the nuts derived from even the same bunch show considerable variations. In an experiment to show this 1,260 nuts were examined at Buitenzorg, Java[13] from different positions on individual palms. It was found that there were fairly great differences in the percentage of copra and in the oil content of nuts where two were taken from the base, two from the centre and two from the top bunches in each palm examined.

According to Cooke[10] ripe Malaya coco-nuts average 0.5 lb. of dry copra per nut, while the highest yield of oil and copra is obtained approximately at the time of natural nut-fall.

E. C. D. Green, Superintendent of Keravat Demonstration Plantation, has made some detailed observations on coco-nuts at Raulawat Plantation, New Britain, but as the investigations are unfinished, details will be presented at a later date. Meanwhile a few interesting figures are quoted in support of the argument for seed selection.

The total weight of nuts where over 30 nuts were considered ranged from 26 oz. to 65¼ oz., with an average of 42 oz. approximately. The weight of husk present ranged from 8½ to 22 oz., while the weight of shell varied from 4¾ oz. to 10¼ oz., and the transverse diameter of the nuts ranged from 9.9 to 12.4 cm. The amount of contained meat varied from 5¾ oz. to 17¾ oz. with a general average of 12.2 oz. approximately. The ratio of meat to total weight ranged from 1:2.7 to 1:7.0 which shows a wide divergence in percentage meat yield and the figures speak for themselves as to the advisability of selecting nuts yielding the heaviest proportion of copra.

Measurements were taken on 100 nuts at random from a representative collection, and the following figures were obtained for the nuts:—

Total weight	3.18	lb. per nut average
Weight of husk	1.395	lb. per nut average
Weight of shell	.45	lb. per nut average
Weight of wet meat	.75	lb. per nut average
Weight of Kruss present (slightly germinated nuts)	.57	lb. per nut average
Weight of dry copra	.42	lb. per nut average
The ratio of $\frac{\text{dry copra}}{\text{total weight}}$ was	13.2	per cent. approximately
While the ratio $\frac{\text{wet meat}}{\text{total weight}}$ was	26.3	per cent. approximately
$\frac{\text{The weight of dried copra}}{\text{husked nut}}$	23.25	per cent. approximately
$\frac{\text{Weight of wet meat}}{\text{husked nut}}$ = ...	41.8	per cent. approximately
$\frac{\text{Weight of dry copra}}{\text{weight of wet meat}}$ = ...	56	per cent yield.

Despite the fact that this is a good yielding plantation it is plainly apparent that the average size of nut and yield of meat could easily be improved upon if all the nuts present even approached the yield of the best nuts present in the random sample.

The following distribution table for 31 nuts depicts the range of variability present even where such a small number is considered:—

Total Weight. Oz.	No. of Nuts.	Weight of Meat. Oz.	No. of Nuts.
25-35	5	5-8	1
35-45	15	8-11	8
45-50	9	11-14	14
50-55	2	14-17	7
		17-20	1

It will be seen that between one-quarter and one-third of the nuts are above average in weight and yield.

Coco-nut Introduction.

The extent to which coco-nut seed introduction into New Guinea has proceeded since historical times is not generally realized, nor has it been indicated. It is as well to point out that all islands of the South Pacific carry coco-nuts. The original habitat of coco-nut palms is doubtful, though some opinions seem to favour its South American origin, particularly as that country is decidedly rich in species of the genus *Cocos*. This subject is well discussed by Hill.[27]

Writers also disagree as to whether the coco-nuts pre-date the arrival of the native inhabitants of the Pacific islands.

The possibilities of coco-nut seed introduction were fully realized by German planters resident in this Territory before the war. Mrs. Forsythe, known as Queen Emma, is said to have introduced selected coco-nuts from Samoa to her plantations at Herbertshohe (now Kokopo). The German Government also imported two of the best kinds of coco-nuts from a representative of the Imperial Government in Samoa to the Rabaul Botanic Gardens, about 1911. The one producing large coco-nuts was introduced as Niu Vai, while a smaller variety was brought in under the name Niu iu.

In the earlier history of Samoan development, native labour was regularly recruited from Bougainville Island for work in their plantations. Seed coco-nuts were thus believed to be brought to New Guinea by the boats travelling backwards and forwards.

Mr. Winand, a planter resident here since 1902, has supplied the information which he gleaned from Mr. Mouton, also an ex-planter of many years standing, now resident in Australia, who was also a member of the "de Ray" expedition. He says that the ill-fated members of that expedition introduced selected nuts from New Hebrides and New Caledonia to the southern end of New Ireland. Palms derived from these nuts are still known to some old planters in the Namatanai district and are said to produce large nuts with thick husks.

One of the first actions of the old New Guinea Company was to introduce selected coco-nuts from some outside source to the mainland near Madang, and probably other places. It is also well-known that there has been continuous interchange of coco-nut planting materials between New Guinea and the British Solomon Islands Protectorate (Solomon Islands) probably since the earliest times.

During the German administration many exchanges of selected coco-nuts were made between districts here. It has been stated on good authority that the large New Guinea Company planted most of its plantations with nuts derived from Peterhafen, Witu Island. These nuts were said to be round, medium sized with thick copra. It is likely that this may be a distinct, regional strain, but there is the possibility of their characteristics being due to environmental effects which may not be reproduced in situations with poorer soils.

Their administration introduced palms bearing small attractive yellow nuts from "Stephansort" apparently at, or in the vicinity of, the plantation Bogadjim. These were stated, in the 1911-13 report on the Botanic Gardens, to have grown well and to be bearing plenty of fruit. Some of these palms are still in these gardens and appear to be breeding remarkably true for the yellow coloration.

Coco-nuts were also brought to Rabaul from Peterhafen and from "Jomba", Madang; these were badly attacked by the rhinoceros beetles and fared badly. Whether coco-nuts from these sources were distributed to outside plantations is not known.

Seed coco-nuts from the British Solomon Islands were introduced by at least three large planting groups to Bougainville Island. In one instance the manager stated that the Solomon Islands palms from which he introduced seed nuts were originally derived from selected seed nuts brought from Samoa.

At Numa Numa plantation palms from three separate districts were grown in comparison with each other, viz., from Rabaul, Bougainville, and the British Solomon Islands. These showed comparatively little strain difference, except that the manager noticed that the palms derived from British Solomon Islands Protectorate nuts came into bearing decidedly earlier than the other plots. Individual palms from all three sources showed great variation in fruit production as would be expected.

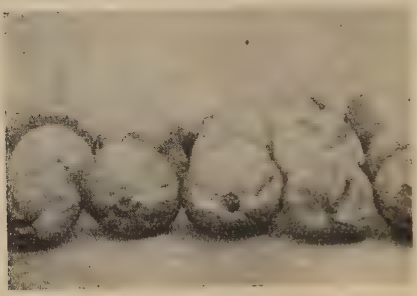
During a recent visit to Witu Islands, opportunity was taken of investigating possible reasons why the New Guinea Company so widely used seed nuts from this source. Another objective was to select good palms for the breeding programme at Keravat. The question is what special attributes prompted the company to use these seed nuts for extensive plantings. Geologically the Witu group is of very recent origin, and it is not many generations since the first seed nuts were brought there. The oldest palms there are not so high nor so old looking as palms seen in other parts of the Territory. Nevertheless, the palms are quite old, and have been forced upwards by the competition of the short surrounding bush. The islands previously supported a much larger population, but a great proportion was wiped out by an epidemic disease which occurred less than 40 years ago, and at present only a few hundred natives are left. Previously extensive plantings of coco-nut groves were made by these old inhabitants, and these still remain and appear exceptionally healthy. The soil, being new, is rather shallow but chemically rich and very friable.

The Germans of the old New Guinea Company made Meto, at Peterhafen, their head-quarters and afterwards for five years this was a copra concentration depot and store for the Expropriation Board, and it was later used for the same purpose by the Melanesia Company. The former company sent seed nuts from this centre to plant new plantations in all districts of New Guinea at such places as Madang and Aitape on the mainland, Bougainville and New Britain. It is said that some were taken to Kar Kar or Dampier Island, which place has also a good reputation as a source of seed nuts, but this is doubtful as probably most of the nuts planted there were derived from selected palms, either local or from the mainland near by. Paul Schmidt, the German planter who first opened up this island, informed the author that most of the nuts used to plant the original European places there were derived from Alexishafen and Potsdamhafen on the mainland.

Since the Australian occupation, plantations at Garua Island and Talasea were planted with coco-nuts from selected and marked palms at Witu. Inquiries from several old natives reveal that the coco-nuts first used to plant Meto plantation were selected from old native groves on the higher areas of the island. These coco-nuts are mainly growing at an altitude from 700–900 feet, and were planted by earlier inhabitants. The writer was conducted by an old native pensioner living on Ilia plantation, to see the palms from which these seed nuts were obtained. It is easy to imagine why these palms were selected as mother palms for seed nuts. Even at the present time (October, 1937) these original

old palms are bearing heavily, and the nuts are usually round, of medium size, very meaty, and heavy in proportion to size, with a husk which is not unduly thick, while the frond canopy is a healthy green in colour. The number of nuts per ton at Meto has been ascertained as being approximately 5,000, hence they are not so big or so heavy as the Markham Valley or Kar Kar Island nuts. The first plantings at Meto were made in native fashion, not being properly lined or spaced, by a Malay in charge of several "Marys" (native women), but the later plantings were more carefully lined. Several old boss boys and old natives in villages were independently questioned, and they all agreed regarding the areas from which the seed nuts used were derived. Some of the boys questioned had been actually engaged in collecting the original seed nuts. There are numerous old palms left standing on the flat areas, but apparently these were not used to provide seed. The nuts used were selected by natives only from what they considered to be good, heavy bearing palms, and no other supervision was exercised.

PLATE VI.—SEED COCO-NUTS.

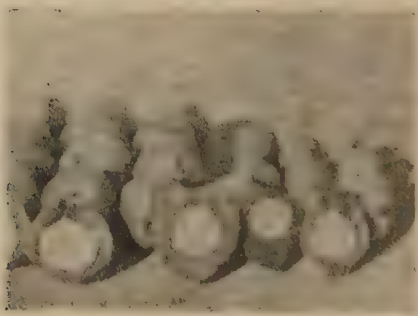


Good type, from Meto Plantation, Witu Island.

PLATE VII.—SEED COCO-NUTS.

Good type, from Meto Plantation, Witu Island.

PLATE VIII.—SEED COCO-NUTS.



"Split Open." Good type left of photo; bad type right of photo.

According to some of the natives these old native groves also provided many seed nuts which were concentrated at Meto for despatch to other parts of the Territory, and it was not until the palms were well in bearing that plantation nuts were used for this purpose. Thus it is practically certain that comparatively large areas of New Guinea plantation coco-nuts were derived from Witu coco-nuts, originally grown by natives.

Despite the age of the coco-nut palms at Meto, namely, 40 years approximately, and the haphazard plantings on this plantation, it is still yielding more than a ton of copra per hectare. The palms still have a healthy appearance and the individual palms are yielding much better than the yields given would indicate as there are many misses in the planted areas, and it is difficult to find really bad palms. It appears that there is a bigger proportion of reddish-yellow nuts, not brick-red nuts, than is usually seen.

If it is granted that the Witu coco-nuts have rather distinctive features, is the environment responsible? It would, undoubtedly, have a great influence on the resultant nuts. It does not appear, however, that the presence of the distinctive, rounded type of moderate sized nuts, often seen at Witu, is altogether due to environment or accidental causes, and it becomes necessary to consider the question of native selection.

It is feasible that a proportion of the coco-nuts brought to Witu came from the same centre as the original natives. Probably a big population did not develop until some time after their food plants had increased sufficiently, as the natives there do plant bread fruits, mangoes, eugenias, galip nuts (*Canarium spp.*) more extensively than in other parts of New Guinea. The original plantings were made in distinct groves as they can be seen to this day, close to old village sites which have now largely disappeared. The first introduction of seed nuts was most likely not extensive and it may be assumed that only better than average nuts were planted so that the foundations for a varying but regional strain were commenced. Numerous people here doubt the very possibility of natives having any idea of seed coco-nut selection. The author has tried out certain intelligent natives as to their knowledge of coco-nuts from this aspect. Allowance must be made for the possibility of their having seen some selection work done, but this would not be true of every case. Natives from certain parts of New Guinea do select nuts for planting in their own groves. Indentured boss boys on three plantations in Witu were asked to select palms in front of myself and their managers. These boys may have seen selection work carried out; nevertheless, without any guidance and in all three instances, the boys instinctively selected good palms after carefully looking over them and roughly tested the weight of nuts in their hands. The intelligent boys assured us that they actually use similar criteria for selecting good seed nuts in their villages. The aid of such boys would greatly simplify any programme of seed selection commenced by the planter.

From a genetical point of view and on theoretical argument, the planting of relatively few selected nuts at high situations would isolate the palms, even if it were done unintentionally. Then, owing to limited intercrossing, a distinct but, of course, variable strain could be evolved in this manner. In what degree this has led to the development of Witu nuts is only conjecture. According to Mr. Mills, the present manager of this plantation, the nuts derived from Meto have tended to give a low percentage of germination when shifted elsewhere and he gave a figure of as many as 40 per cent. being non-viable. If such is genetical, these seed nuts would not be so useful for new plantings as is claimed, but there may be other causes for this. Numerous introductions from Meto plantation to Keravat have already been made by this Department.

In German times seed coco-nuts were imported from Meto to Bali and from Bogadjim plantation on the mainland and were apparently selected for size and weight. Some plantation areas show a rather high proportion of heavy bearing brick-red nuts which may have come from the mainland. After the Australian

occupation about half the main bearing area at Bali was planted with seed nuts derived from the older palms which grew from originally imported seed. It is only very new areas at the rear of the plantation which were derived from local native palms.

Local native coco-nuts seen in the villages were usually smaller, more pointed and not nearly so heavy as those from plantation palms. It must be conceded that this diminution in size may have been caused by closer planting and competition with secondary bush. Though growing on similar soil the native nuts at Bali were quite a different type from those seen in the native villages at Witu, near Meto plantation, while the introduced nuts appeared superior to the local nuts on the plantation at Bali. It is thus believed that unconsidered selection was practised when the original selected nuts introduced by the Germans were used as a source of seed nuts for further plantings.

Members of one firm here which have introduced large selected nuts from Kar Kar Island to plantations in other parts of the Territory claim that they have fared better than local palms.

Lever's plantations in the Solomon Islands are said to have introduced nuts from several different countries such as Malaya and Fiji for comparison with local nuts. Managers have stated that palms derived from all these sources were far more liable to beetle damage and did not fare so well as the local nuts. This curiously coincides with the experiences where Markham nuts were introduced to Keravat and earlier when other types were introduced to Rabaul, but no good reasons can be advanced as to why this should happen.

The present Department of Agriculture has carried on a great deal of coco-nut seed introduction from outside countries and also from the various outlying districts in New Guinea. These are at present being grown under the supervision of the Superintendent at Keravat, but in most instances are too young for detailed observations on their behaviour.

The Director of Agriculture observed some palms growing in the Solomon Islands which were originally derived from seed of already selected tall palms growing in Malaya. These were 26 years old and bearing heavily. Re-selections derived from this area were introduced to Keravat Demonstration Plantation, in January, 1934. In January, 1935, seed coco-nuts derived from the best selected palms which had been subjected to yield recording for some years at the Landbouw Instituut, Buitenzorg, Java, by the Selectionist for perennial crops, Mr. de Veer, were introduced as part of a large consignment of plants brought in by the present author. More recently during this present year (1937), and through the courtesy of the Director, selected coco-nuts were introduced from palms which had been under observation for some years at the Coco-nut Research Station, Menado, Celebes, Netherlands East Indies.

A request has also been forwarded to the authorities in Manila, Malaya and Fiji for any selected coco-nuts of various kinds, which may be available at their research institutions.

In addition to the above programme of introduction, coco-nuts from selected palms on plantations growing in all parts of the Mandated Territory of New Guinea have been collected for inclusion in a breeding programme at Keravat. The following districts and sub-districts are represented in this collection: District, New Britain—Rabaul, Talasea and Gasmata, Sub-districts. New Ireland. Witu Island, Dampier Island, Bougainville Island, and the mainland of New Guinea.

The coco-nuts derived from the Markham Valley, particularly in the upper Atzera region, have been generally noted for their large size, perfect shape and good yield, and this has been commented on in several reports by Patrol Officers of the District Services, as well as by officers of this Department. In October, 1929, a large consignment of these coco-nuts was introduced to Keravat and planted out in an area isolated from coco-nut palms, at the Demonstration Plantation, derived from other sources. These palms have retained, to a marked degree, the original characteristics for which they were introduced under the widely different soil and environmental conditions which prevail there as compared with their original habitat. Mr. Moody, Inspector and Instructor, says that when these nuts were introduced to Lindenhafen, New Britain, they tended to break-up and become more pointed than is usual for the Markham nuts, but, although varying, still showed many of their original characters. It is possible that these coco-nuts did not come from the same area as the nuts growing at Keravat. At Keravat, these Markham coco-nuts, although still varying in colour and size of nuts, are very similar in general type and appear quite distinct from the ordinary native coco-nuts growing in New Britain, and could be classed as a regional strain. Their trunks are apparently shorter and require fewer nuts to produce a ton of copra than nuts from ordinary palms—less than 4,000 nuts as against between 6,000 and 7,000 nuts per ton for ordinary nuts in the vicinity. The nuts have a fairly thick husk, however, and it has not been determined whether their total copra yield per acre is superior to the ordinary types. At Keravat, for instance, the yields have not been compared with coco-nuts derived from local seed. The selections of the heaviest yielding palms were made for inclusion in the breeding programme, and are already planted out as will be described later. All the poor type palms have been eliminated. This plot of palms has been particularly liable to infestation by palm weevils. The Superintendent, Mr. Green, is inclined to believe that this may be due to a varietal tendency for the wood to grow soft. The isolation of a small group of palms would in itself lead to increased infestation, however, because of the greater limitation of the food supply of these various pests. The presence of such a regional strain seems to indicate a more encouraging future for coco-nut breeding than is usually anticipated. The question as to the origin and the presence of such a regional strain on particular areas of the Markham River country is very interesting and needs further study. It is reasonable to assume that the natives in this area may constantly practise seed selection with a definite objective in view. There is also the possibility of natural selection going on over many years having a similar effect. A more important consideration is whether this strain is more liable to self-pollination, than other types, owing to a different hereditary complex, and pollination studies are necessary to determine this point. Mr. O'Brien, planter from Madang, has provided some data which seems to have a more likely bearing on the point He has heard from old residents around Madang that Erima Beach plantation was one of the first places commenced on the mainland by the old New Guinea Company. The nuts introduced there by them were specially brought in as selected large nuts of a particular type. Some plantations planted with selections of this type are still known in that vicinity, and it is thought that the natives in the Markham may have obtained their seed from nuts originally derived from the original introductions. The diameter of husked nuts recently brought in from Madang by Mr. O'Brien ranged from about 6 inches to 8 inches while their diameter is greater than the depth, i.e., ovate. There was a tendency to ridging and the kernel was very thick. Whether such large nuts would produce

more per acre than ordinary nuts is not proved, but some planters near Madang are quite convinced that they do.

It might be said that there is no object in breeding or propagating regional types unless it is proved that a particular form is superior to any other. The San Ramon type of coco-nut later mentioned under varieties, appears to be an example of superior regional type. Copeland[11] says, "That there are no records from any other part of the world of plantation averages showing such size of nut as those of San Ramon. In 1905 for the entire plantation, an average production was one metric ton of copra from every 2,800 nuts, while the average production from year to year shows that 3,270 nuts are needed to produce 1 ton or 2,240 lb. of copra." According to the annual report of the Coco-nut Research Scheme, Ceylon, 1935,[7] all other introduced types, with the exception of this variety, proved inferior to local varieties both in yield and susceptibility to beetle attack and quality of copra. It was mentioned that a similar type of this is found in several coco-nut countries of the East. It does appear roughly comparable with the Markham type found here. In the small island of Rotuma, Polynesia, there is another example of a superior strain. This island has been noted for the superiority of its nuts, which have been used for seed in Fiji, Tonga and other places. Coco-nuts from certain areas in the West Indies have been similarly noted for their use as seed nuts, e.g., at San Blas and parts of Jamaica.

The "San Blas" coco-nut of Central America has the layers of cells between the shell and the endosperm which are peculiar in breaking up so that the meat, kernel or endosperm is very easily removed from the shell. This race has been introduced to Malaya and deserves to be introduced here. It may be mentioned here as a noted fact concerning coco-nuts from some areas of the British Solomon Islands, that the half-kernels are easily removed from their shells. Whether this is due to soil or strain effect is not yet proved. In Bali there is a large coco-nut which has been widely distributed in the Netherlands East Indies, and this is known as the "Bali Klapper" in Java.

Smith[57] has indicated rather disappointing results with the "San Blas" coco-nut in Malaya. The palm differs in many characteristics from the tall. In general appearance is midway between that and the green dwarf. The stem is slighter; measurements of twenty palms of each variety at 6 feet gave an average girth of 30.3 inches San Blas, and 38.5 inches tall. The "San Blas" averages about 5 or 6 feet shorter to the lower leaf but the leaf is longer as is the spadix. The chief characteristic on casual observation is the very open crown and the large number of leaves hanging down more or less vertically. The fruits are much more elongated than the tall as is the nut proper inside. They have a very high husk percentage amounting to 43.7 per cent. of the whole fruit compared with 26.1 per cent. for tall.

—	Husk.	Wet Meat.
	Per cent. whole fruit.	Per cent. whole fruit.
San Blas	43.72	25.26
Tall	26.15	28.85

Smith concluded that although the "San Blas" coco-nut has the reputation, in Central America, of being an extremely prolific yielder, it did not suit the heavy alluvial clays of the west coast of Malaya, when compared with the ordinary Malayan tall variety.

It may be pointed out that the regional strains, which have been described from Witu and the Markham Valley, could contain representatives of several of the "races" such as are described by Webster.[64] It is a wider term in the sense that it represents a collection of types constituting a strain which, owing to the long effects of natural selection, do show certain characteristics in common.

According to Crocker, Inspector and Instructor, one bag of San Ramon coconuts was introduced to Namai Plantation, Papua, by Mr. J. C. Hammett in 1919. When they first came into bearing the nuts were very big, but the yield was not very profuse; whether they did better later on is not known here. There is no record of the introduction of this type of nut to the Territory, but it should be introduced and tried out under varying environments in different districts, as some of these may give full expression of its yield capacity.

Genetical Abnormalities.

The following genetical abnormalities were recorded in a previous article on coco-nut diseases[16] as being present here. No palms showing genetical defects should be used as seed producers.

Yellowing of the Palms.

Genetical chlorosis is known here and even in the best plantations palms showing a genetical lack of chlorophyll are known.

Female Palms.

Male flowers suppressed; nuts often without embryos or with very little copra.

Soft Copra Produced by Particular Palms.

Such copra does not cure properly and remains soft and leathery.

Branching and Twin Palms.

The presence of true branched palms with up to eight branches was first recorded by Preuss[50] for New Guinea.

Bulbiliferous Coco-nuts.

At least eight investigators have recorded cases in which bulbiliferous coco-nuts with deciduous and sterile inflorescences develop small leaves instead of flowers.

Leaf Bases Remaining Attached to the Palms.

Either on the whole or portion of the trunk.

Head Droop.

This was recorded as a suspected virus disease in the article mentioned (*see* pages 71-76) and it was suggested that it would be definitely unwise to select seed coco-nuts from areas where "head droop" is prevalent and that seed nuts even from good palms growing close to a palm suffering from this condition should be avoided.

Gummy Leaf.

This is a condition common at Witu and other parts of the Territory where the pinnules (leaflets) of the palms remain held together and depressed to the midrib. Such palms produce hardly any nuts and should be avoided in the same way as "head droop" palms.

Frond Choke.

This is another common malady in coco-nut palms here. It is undoubtedly mainly present in weak-growing palms which lack vigour. Seed nuts from such palms should be rigorously avoided as they never become good, healthy palms.

Constricted Nuts.

The nuts become constricted in the centre, are very pointed and do not fill properly which is probably an hereditary defect.

PLATE IX.—COCO-NUT PALM.

Showing tendency to "Frond Choke".

Coco-nut Varieties.

Omar[43] says that in Singapore Island fourteen different races exist, twelve differing from each other in the nut, and two differing also in growth. The Malays have named four types from which most of the Singapore copra is made—

"Kĕlapa bulat" (round coco-nut), "Kĕlapa besar" (big coco-nut) and "Kĕlapa jantong" and "Kĕlapa sapang" (both heart coco-nuts). Another common race "Kĕlapa laga" is too small for copra. He mentions two rare types, "Kĕlapa nipah" and "Kĕlapa hyau", which promise big yields of nuts suitable for copra making, and also the dwarf coco-nuts "Kĕlapa puyoh" (quail's coco-nut) which is green and the "Kelapa gading", the common yellow dwarf.

Other nuts with special uses are "Kĕlapa dadeh" (curd coco-nut) which, in about 5 per cent. of nuts, has detached granules of endosperm in the milk and is eaten with sugar as a delicacy. "Kĕlapa kuning" (yellow coco-nut) has more sugar in the milk and is reserved for eating while the nuts of "Kĕlapa loji" are eaten young. (Races similar to these are present in New Guinea.) "Kĕlapa wangi" (fragrant coco-nut) with a scented meat and "Kĕlapa sekol" the shell of which is fancied for cups. Burkill[6] says there are twenty races recognizable at Kuala Kangsar, Malaya.

Stockdale[60] has described nineteen varieties from Ceylon which are said to be distinct from each other in respect of external features such as shape and size of nuts. Four were said to be special types, namely, the "tembili" or "king" coco-nut, the "yellow gon-tembili", a large imported nut resembling the large "San Ramon" which was also described, and another imported nut. The others were divided into nine main groups from detailed measurements and other particulars taken. Copeland[11] mentions the "San Ramon" nut of the Philippines as being the characteristic palm of the San Ramon district which has been distributed to all parts of the country by their Government. He regards the "Laguna" nut as the ordinary coco-nut of the Archipelago as a whole and it appears comparable with the typical ordinary coco-nut throughout the world.

Copeland and others have listed amongst other varieties "Coco nino" or "baby coco-nut" from the Philippines which produces fruit at the age of four years, when the trunk is so short that the nuts can be collected for several years by a person standing on the ground. The "Pugai", a very dwarf nut, is also mentioned, with a diameter of about 7 c.m. when husked. This fruits in three years and the very small nuts are used as curiosities.

He says, "that as clear cut and distinct as are the 'San Ramon' nut, the 'Laguna' nut and the two dwarf forms, when only these four forms are considered, it would probably not be difficult to collect in the Philippines an unbroken series without a break of 1 millimetre in diameter which would connect the largest and the smallest nuts and an equally perfect series could probably be found in other countries".

There is a variety in the Philippines which although not the same is not unlike the type found in the western islands. This variety, known as "Makapuno", has no cavity inside the hard endosperm, but instead there is moderately light but still firm tissue filling the entire interior of the nut. Such nuts do not germinate, however, and may be produced on the palms, part of which produce ordinary nuts. A similar nut is found in Java and in both countries it is valued as a delicacy. One hundred nuts of this type were recently brought into the Botanic Gardens. Many other varieties have been described, e.g., with extremely hard shells, usually thick husks, soft endosperm, blackish green husks and so on. It is not known for certain how the variations in types found in one country compare with those found in another, but there do seem to be varieties which are common to all parts of the world.

Hunter and Leake[28] writing on this subject say, "that the number of coco-nut varieties has not been accurately determined, partly because of the difficulties inherent in any such determination in the case of a plant of such wide distribution and with so long a life, and partly because of the lack of genetical purity, due to the fact that cross-fertilization takes place normally". Wester, 1920,[64]

enumerates over 80 names, many of which are no doubt synonymous, but he has by no means exhausted all the types available from all parts of the world. The most distinct variety is the dwarf coco-nut, but other very distinct types are known. There is a variety present in New Guinea whose appearance and behaviour would suggest an entirely different hereditary and chromosome complex. The type referred to is widely distributed and has been seen by the author in New Britain and Lavongai Islands. It has also been recorded from Bougainville Island and is undoubtedly present on the mainland. This coco-nut is well known to the natives who relish the edible husk. The whole husk as well as the interior of the nut is edible until a late stage of maturity and is sweet and said to be palatable although it turns red in the mouth. The variety with sweet or sugary husk is called "Tabau" or "Cuyamo" in the Philippines and "Kĕlapa Tebu" in Java. It should not be confused with a variety found in several parts of New Guinea which has a more sugary endosperm or kernel and is thus especially prized by the natives, such as in the Huon Gulf area and in parts of Bougainville.

It appears to the author that this is really a genetical abnormality, and that the whole edible portion consists mainly of a proliferation of soft terminal cells from the flower branch, such as is seen on the true growing point of the palm itself, which is also much liked by natives and has been named by Europeans the "Millionaire's Salad". Coco-nut palms which produce almost entire leaves, branching coco-nut palms (one growing on an island here, stated to have five trunks; palms with up to ten stems have been recorded elsewhere) and those palms which produce female flowers only, are probably mutations (sports) which on crossing should behave as mendelian characters and be inherited in distinct ratios. There is also the possibility of an aberrent number of chromosomes being present in such cases which lead to abnormal developments.

There is a distinct field for a good cytologist who could study the cell structure and the chromosome number and behaviour of such off-type palms and thus learn much which would be of value to workers studying pollination and fertilization problems, or to those engaged in coco-nut breeding. One has only to turn to the value of such findings to workers on tobacco, maize and fruit studies to know how valuable cytological findings can be in elucidating difficult problems. As far as it is known the only investigation on the nuclear constitution of the coco-nut was conducted by Santos, 1928,[53] who finds that the haploid number of chromosomes present in the germ cell is sixteen.

Several true branched coco-nut palms have been described by Paul Preuss, 1911,[50] from the mainland of New Guinea and he includes a photograph of one palm from Matty Island with six stems. In his book he also describes six coco-nut varieties from Samoa and says that there are at least ten or twelve varieties in the Bismarck Archipelago and mentions a dwarf red variety as being present here. Branched coco-nuts are still known in some of the outlying islands of New Guinea.

Dwarf Coco-nuts.

It is pointed out, however, that the green and yellow varieties of the dwarf coco-nut from Malaya were introduced in 1930 and have been in bearing for some time at Keravat. They have also been tried out on a small scale in outside areas.

Handover[26] expressed the opinion that the Malayan dwarf race known as "Nyior gading" first originated as a sport or mutant in Java. Other apparently distinct dwarf races are known in the Philippines, Fiji, Madagascar, Ceylon, Maldini and Nicobar Islands. The above authorities[31] from observations show that the dwarf coco-nut from Ceylon is quite distinct from the "Nyior gading" and they give reliable descriptions of the two types together with the Philippine dwarf variety, "Coco nino", which is also a distinct type.

In Fiji dwarf coco-nuts are being grown and the Malayan dwarf has been crossed with the local dwarf coco-nut called "Niu luka"[1] an example of hydridization. Some of the resultant selections bear coco-nuts before the spathes rise above the ground. These should provide very interesting material as they have been artificially crossed and re-selected. Investigations on this cross show that it is liable to cross fertilization in Fiji.

With the idea of selecting superior dwarf palms from this cross, coco-nuts of individual palms were submitted to chemical examination in their first and second years of bearing. It was found that the weight of meat per nut varied from 361.4-531 grams on a wet basis, while the percentage of oil per nut (wet basis) varied from 23.76 per cent. to 39.92 per cent., hence considerable variation in these characteristics was apparent.

So far the cultivation of dwarf palms has not spread here although it has been the subject of many inquiries to this Department owing to its reputation for high yield in Malaya. Yields of around 30 cwt. to the acre are obtained under some conditions such as at Chersonese Estate.

PRODUCTION OF DWARFS AND TALLS COMPARED.

The figures for dwarfs are average from six estates—after Jack and Sands.[32]

—	Dwarfs.	Talls.
Number of palms planted per acre	90	48–55
Crops in pikuls per acre 4th year	2.29	..
Crops in pikuls per acre 5th year	6.19	.5
Crops in pikuls per acre 6th year	7.52	2.00
Crops in pikuls per acre 7th year	9.24	4.00
Crops in pikuls per acre 8th year	11.68	6.00
From 10th year (estimated)	13.00	8.73
Number of nuts per pikul of copra (mainly yellow) ..	560 (approx. 9430 per ton)	251 (4230 approx. per ton)
Number of nuts per pikul of copra—average of two estates (mixed dwarf palms)	482 (approx. 8118 per ton)	251
Number of nuts per pikul of copra—Green race only (estimated)	430	251
Weight in grammes of copra per nut to nearest 10 grammes	130 (.29 lb.) (4.68 oz.)	268 (9.36 oz.)
Number of nuts per palm per annum (conditions favorable)	90	56
Production of copra in pounds per palm per annum (favorable conditions)	25	32
Production of copra per acre per annum in pounds (favorable conditions)	2,250	1,600

Average oil content of copra = 64.78 per cent. and 7.74 per cent. (moisture).

PARTICULARS OF AREAS OF DWARF COCO-NUTS, CHERSONESE ESTATE.[63]

Area—41.05 acres. Date planted—1920.

Planting distance—22 feet x 22 feet square giving 90 palms to the acre, but owing to the fact that bunds and channels are included in the planted acreage the total number of palms is only 3,488 and the average number of palms per acre just under 85.

Varieties—

Dwarf "red" .. .. 3 palms.
Dwarf "greens" .. .. 90 palms.
Dwarf "yellows" .. .. 3,395 palms.

Year.	Number of nuts harvested.	Average number of nuts per palm.	Copra per acre in piculs.	Number of nuts per picul of copra.
1925	194,530	56	7.83	604
1926	235,360	67.5	9.54	600
1927	209,876	60	7.24	707
1928	386,876	111	14.33	646
1929	235,444	67.5	8.96	602
1930	369,056	106	14.88	592
1931	371,645	106.5	14.93	590.
1932	345,208	99	15.18	531
1933	514,091	148	25.99	457
1934	470,028	135	23.56	461
1935	531,219	152	27.60	458

NOTE.—1 picul = 133⅓ lbs.

Intensive irrigation was introduced in 1931 and fewer nuts were required per picul of copra in 1932. In 1933 and subsequent years, yields have been phenomenally high and the nuts have been very much larger than formerly.

In view of the results already recorded, the writers feel justified in anticipating potential yields of at least 30 piculs of copra per acre from the new area described above planted with "dwarfs" in 1935, and also the area it is intended to plant this year (1936) with the same variety making the total of 324 acres.

Lennox,[37] a visiting scientist from Hawaii, informed this Department that they have bearing dwarf coco-nuts in that country which fruit before the spathes are much higher than the ground level. The Mangipod variety in the Philippines is also said to produce fruit when the tree is so small that the cluster rests directly on the ground. Malayan dwarf coco-nuts have been tried in Papua and according to Moody, Inspector and Instructor of this Department, who was resident there for some time, they came into bearing and yielded well, but the copra was inclined to be leathery and not quite such good quality as the product from ordinary palms.

The utility of dwarf palms to New Guinea conditions is not yet apparent as this variety is far more particular in regard to soil conditions where it is grown, than is the case with ordinary coco-nuts. The growing of dwarf coco-nuts here is only in the experimental stages and it would take a long time to build up sufficient material for planting on a large scale. Copra from dwarf coco-nuts grown at Keravat has been cut and dried at Kabaira Plantation, but did not produce such

a good sample as ordinary copra, being softer and more pliable. Seed nuts from Keravat were planted out at intervals on higher ground at the back of that plantation. Seen as young palms they do not appear to be flourishing yet on this light rather pumaceous soil.

It may be of interest to record that one natural dwarf mutant palm was seen along the Kokopo road close to Rabaul, before the recent eruptions.

What would be more surprising to a great number of people here is to know that dwarf palms yielding reddish nuts are grown in many native villages along the Aitape coast on the mainland of New Guinea. Wood, Inspector and Instructor, stated that "the natives themselves indicated that the nuts first came through from the Dutch border in the course of their usual trading". He noticed that in nearly every village a small number of these nuts were grown alongside the tall nuts and were yielding profusely. For some reason they are usually "tambu" (forbidden) to the native "Marys" and only the boys eat them. It is probable that these are Malayan dwarf coco-nuts originally sent to Dutch New Guinea. These are now being grown in villages 150 miles from the Dutch border. It is easy to realize how similar planting material could have been spread by natives before the advent of white man here.

As these nuts appear to be flourishing under the local conditions they should form a good source for seed supply. Some intermediate types present at Aitape show the chances that some crossing with tall palms has occurred. It has been stated that though the yield per plant, despite the number of nuts borne, is less than that of the tall variety, the larger number of palms carried per acre more than counterbalances the deficiency. Dwarf coco-nuts are earlier maturing than tall coco-nuts and produce 700-900 nuts per acre from the more closely planted palms, but it takes approximately 8,000 nuts to the ton of copra. When the conditions are exceptionally favorable the yield of copra is far greater than from the tall palm, but the yields are unsatisfactory where the soils are unsuitable. While in Malaya the author was informed that the dwarf red nuts are very sensitive to unfavorable conditions, but that they give a very fine yield where the circumstances are ideal. The copra and oil are not so good as that derived from ordinary palms.

According to Jack and Sands[32] the average period which elapsed from planting to flowering of dwarf coco-nuts, in Malaya, was for yellows, 3 years, 86 days; reds, 3 years, 105 days; greens, 3 years, 263 days. The green types commenced flowering at uneven periods which was thought to be due to the greater genetical impurity of the strain.

The germination results of the second generation of nuts showed that, in respect of colour of the young shoots and subsequent growth, they were apparently true to the type of palm from which they were taken. This suggests that they are self-pollinated and breed true.

Mr. Murray, Director of Agriculture, says that during several visits to Malaya he found that opinions varied regarding them. The manager of one large estate had several hundred acres under dwarf palms, but he considered they were most unreliable and very variable as to production, even in the same field.

Referring to dwarf coco-nuts in their "Consols of the East", Smith and Pape[58] stated that two estates, "Sungei Nepap" and "Chuah", in Malaya have 500 acres of the "Nyior gading" dwarf coco-nuts in cultivation. These plantations

are in the Coast District of Negri Sembilan. The young trees which were planted 20 feet x 24 feet, giving 90 to the acre, are doing well. Preliminary expenses were rather heavy owing to difficulty in procuring seed. The palms should come into bearing in about four years, which means not only a shorter time and less expense on upkeep before revenue is obtained, but also a quicker return on money invested. It remains to be seen whether these advantages and the probable higher yield of nuts per acre will compensate for the greater expense in husking, &c., per lb. of copra obtained.

Chersonese Estate in Perak, Malaya, is exceptionally well suited for this variety and after the experiments carried out by the late manager, Mr. H. Wardlaw,[63] it was intended to plant another large area.

Soil for the dwarfs should be of heavy nature though pervious to water, and provided that the sub-surface water is moving a comparatively high water table is no disadvantage. The area in Chersonese Estate under "dwarfs" is on a peninsula, the sea on one side and salt water river on the other. The land is all bunded to prevent flooding with tidal waters (the tide averages a rise and fall of 3 feet) and provided with drainage and irrigation channels, water gates to be opened or closed as necessity arises. This system has resulted in a considerable increase in the size of the nuts.

Cooke and Jagoe[66] have shown by experiment that the copra from dwarf palm nuts is of inferior quality to copra prepared from ordinary tall palm nuts in a good kiln. It is difficult to prepare hard copra from dwarf coco-nuts and usually a large proportion of wrinkled, distorted, rubbery copra is produced.

SUMMARY OF RESULTS.

Copra ex—	Appearance (in order).	Percentage of rubbery pieces.	Nuts per picul of copra.
Tall nuts	Good	0–10	200–284
Green dwarfs	Fair	10–36	350–370
Yellow dwarfs	Poor	18–80	477–667
Red dwarfs	Very poor	50–92	370–513

They also concluded that the dwarf palms appear to favour a soil stiffer than that which is most suitable for tall palms and require greater attention to drainage and respond rapidly to improvement or deterioration in conditions. While very remarkable yields are obtainable at an early age if conditions are favorable, in most instances yields are only fair, or poor, because the conditions do not suit the exacting requirements of the dwarf palm. Early in 1933 they stated that "information had been received from estates with both tall and dwarf palm cultivation that, at least for the immediate future, only tall palms will be planted in new areas or as supplies, even though in two instances yields were good".

Dwarf Coco-nuts in Samoa.

Hamilton and Grange[25] referring to dwarf varieties for Samoan conditions state that "seven varieties which bear at an early age are now under trial at Vailele Plantation, having been obtained from the Agricultural Institute,

Buitenzorg, Java. A further type was observed under trial at the Central Agricultural Station, Navuso, Fiji. Here an attempt is being made by crossing to combine the best qualities of the Malayan dwarf coco-nut with those of the native dwarf "Nui leka". The F1 progeny shows considerable variation and the F2 generation may be expected to show further segregation. The "fixing" of a desirable type is likely to be a matter of some difficulty. Some of the F1 progeny have commenced bearing at three and a half years from the time of harvesting the parent nut. The experiments will be watched with interest, and as soon as the work progresses to a suitable stage, propagating material should be obtained for trial in Samoa. It is unlikely that under present plantation methods these dwarf varieties will fill any useful place in plantations, but owing to their rapid bearing they may fill some place in the native economy under special conditions".

In Malaya it is said that the profitable bearing life of the dwarf coco-nut is not so long as that of the tall coco-nut, which is an important consideration. The larger nuts from ordinary palms are decidedly more valuable than small nuts from dwarf palms, where two types of equal total productiveness are compared, because it costs as much to open a small nut as it does a large one. When a given number of small and large nuts are compared the copra can be manufactured more cheaply from the large nuts.

These detailed particulars of dwarf coco-nuts are given because of the recent interest displayed in them by planters here.

The area at Keravat where these coco-nuts are growing is rather heavy and somewhat inclined to waterlogging in wet weather. The palms have fared only moderately well under these conditions so the Superintendent is going to try them on somewhat lighter soils. It is suggested that it would be a good idea to establish trial areas on heavier soils such as at Lavongai (New Hanover) or on some areas at Manus. It is not yet possible to give a definite opinion regarding this strain of nuts, but it appears that they will not be suited to a particularly wide range of conditions in this Territory. The dwarf-red strain of coco-nut was tried out by Germans at Bogadjim Plantation, and even though a couple of entire rows of these palms are still left they are not utilized for their crop.

A few Malayan dwarf palms are growing in native villages at Witu, e.g., several at present at Balangori Village. At Lama Village, closes to Lama Plantation which is a few miles from the former village, there is one solitary dwarf red type of palm which is bearing most profusely. This palm is completely isolated from all except tall coco-nuts, and the nearest of these are about 60 yards away. Thus this palm is either completely self-fertile or else it is pollinated by pollen from tall palms. There is also one solitary dwarf palm similarly isolated amongst tall palms near Meto homestead about 2 miles from the palm described above which is the nearest to it. The yield of nuts on both of these palms is quite as good as would be expected if they were growing close to other dwarf palms. The interesting fact, however, is that these palms were said by the natives to have been brought in originally by a police boy from the mainland, the nearest port being over 200 miles away at Madang. As this boy came from Aitape, it is likely that the nuts were originally derived from Dutch New Guinea. This is a good example of the human agency in seed distribution.

Leaf Development.

Copeland[11] has stated "that in the Philippines the leaves take one and a half years from their first appearance until their full development and that another one and a half years are required for fruits to mature in their axils. This period could be expected to vary according to climatic and outside conditions".

In the case of dwarf coco-nut palms it is stated[32] that "the number of fully opened leaves of all ages, which form the crown, may vary from 24 to 28 in palms up to seven years old. As a rule there are from eight to ten expanded leaves above a spathe which is fully opened".

The rate of leaf development does not follow any set periodicity such as may be thought, as it is dependent on several variable causes. It is less rapid in the wet season than in the dry season and, further, there is usually also more leaf fall in the wet season. When the palms are carrying a heavy crop of nuts leaf development is slowed down. Even the number of leaves present on one tree varies from time to time and, of course, there is a wide variation in the number of leaves normally produced by individual palms. The recent volcanic eruption in May last greatly affected many thousands of palms, causing them to assume an umbrella shape, while in many cases only the central unopened fronds remained standing. Six months afterwards it is seen that in many cases, six and seven leaves have developed to between half and three-quarters of their eventual size. The indications are that many of these fronds will develop together almost within a few months of each other. If such were not the case these palms would take many years to recover instead of a couple of years as is expected. Of course, this may be the result of unusual circumstances, and the newly derived pumice soil has possibly forced the growth somewhat. Similar observations have been made, however, after a fire has passed through a plantation heavily infested with kunai, *Imperata arundinacea.* The fronds may be almost completely blackened off, but after a couple of years the palms may almost completely recover.

The rate of leaf development is directly related to the subject of this article because of the fact that it is so closely related to the development of the flowering branches. Since each leaf normally produces a flowering branch in its axis, their appearance roughly represents the rate of leaf development when those which are abortive are taken into account. As Sampson[52] has dealt very fully with this subject in his text book, it is not proposed to dilate on it. He says that, "if a tree is not thriving the rate of leaf growth and length of life is greatly lessened compared with a vigorous tree".

In regularly bearing trees the average number of leaves formed in a year is about fourteen and a variation has been noted of from twelve to nineteen in the same year on different trees. In brief, it might be said that all the factors which determine leaf development are related to fruit development, as the leaves are responsible for the elaboration of the plant foods brought to them in the cell sap from the roots. A tree with a compact crown and a large number of leaves will, almost invariably, be found to be a regular and heavy cropper.

Floral Morphology of Coco-nut Flowers.

The structure of the coco-nut flowers (floral morphology) is well known to botanists generally and has been described in many text books and periodicals (*see* [6–8–22 34 36–45]); thus it is not proposed to dwell on this subject except to present a general description in order to acquaint planters of the subject.

The biology and physiology of the coco-nut flowers, as well as the detailed life history of the flowers and fruit through all its stages, are much less known, but, nevertheless, a considerable amount of work has been done on this subject. Coco-nut spathes are formed in the axil of every leaf but are not always seen as mature inflorescences. All planters when cutting down palms have noticed the presence of abortive, i.e., permanently undeveloped, spathes which could not be

PLATE X.—COCO-NUT SPATHES.

Early stages, showing male and female flowers.

A.—Just opening (curiously, some anthers shedding pollen). B.—Spathe opened (male flowers intact).

seen externally, until the fronds were removed. This explains why the number of spathes produced does not often correspond with the number of mature fronds seen. Sampson and others have described the spiral arrangement of the fronds on the stem so that every sixth leaf opens nearly above the first one, and this spiral may be right-handed in some palms or left-handed in others.

Planters are also well aware of the fact that the much-branched inflorescence is at first contained within a thick, fibrous sheath called the spathe, which in its earlier life is in turn covered by an outer yellow, flat softly-fibrous sheath. This outer sheath does not last long, being pierced at an early stage by the hard point of the inner sheath usually on the ventral side facing the lower leaf. This latter emerges as a yellowish, flattened cone which later becomes more tubular in outline.

PLATE XI.—COCO-NUT SPATHES.

First two stages (same as above). Additional spathe showing female flowers receptive, male flowers shed.

Until the spathe is fully grown the branched inflorescence is tightly compacted so that it is quite impossible for the flowers to open before the spathe splits. The whole inflorescence is known to botanists as a "spadix" because it consists of many flowering branches (spikes) which are arranged in spiral fashion, situated on a fleshy, central-flowering stalk (peduncle). The development of the inflorescence within causes so much pressure on the walls of the spathe that it

very slowly ruptures longitudinally, usually on the lower or ventral surface. It is said to take more than one day before the inflorescence finally makes its egress. There is usually a characteristic downward curve of the spathe so that it acts as a protection on the young florets, besides remaining attached as a collar which protects the base of the main flower stalk. It is common knowledge that the coco-nut bears male and female flowers on the same palm and, as a general rule, in the same inflorescence (known botanically as a "monoecious" plant). According to Furtado (*loc. cit.*), the size of the whole inflorescence may vary from 2½ to 6 feet in length from the tip to the base. Each branchlet is fringed with numerous male florets which are in some instances arranged in lines or groups of up to six or more florets in a row, but in most cases much fewer are present. The female flowers are situated lower down on the branches, and all flowers are non-stalked (sessile or sub-sessile), being attached closely to the branches.

Male Flowers.

Each male floret has six yellowish floral leaves which are arranged alternatively in two whorls, the outer three being about one-third the size of the others. Within these are six hammer-shaped stamens which yield large quantities of powdery yellow pollen which represent the male elements necessary for the fertilization of the female flowers. In the centre of each male floret is a short column (rudimentary pistil) which at the apex is divided into three teeth; at the base of each of these is a nectary, the nectar of which attracts insects, birds, &c. The male flowers open from the tip downwards though at odd times a few flowers open out of order. The variable period during which male flowers on a particular spathe are opening and shedding pollen usually represents the duration of the male phase for a particular palm. Aldaba[4] observed in the Philippines that the majority of male flowers begin to open daily at about six o'clock and dehisce their pollen at about eight o'clock in the morning.

Female Flowers.

The female flower in its early stages, prior to its opening, is a small spherical, or slightly conical body, sometimes almost triangular in shape, which often grows to more than ¾ inch in diameter. It has a great resemblance to a young coco-nut and this may give planters the idea that it is a fertilized fruit, despite the fact that the pistil is still so young and so covered up as to be unreceptive to pollen. In the early days some investigators were inclined to believe that the flower had been fertilized, and the nut formed before the inflorescence opened which idea was, of course, quite wrong. As is the case with the male flowers, there are six floral leaves which are arranged alternately in a similar manner. They are developed so as to enclose the pistil completely, and entirely hide the inner parts of the flower until it has sufficiently developed as to become receptive to pollen. These floral leaves are much larger and thicker than in the case of the male flowers while, in addition, at the base of the whole floret there are two short and broad attachments known as "bracteoles". These are seen to remain attached to the branchlet if the young flowers happen to fall. It is because the floral leaves are wrapped so tightly around the female flower that it has often been taken for the fruit. Just prior to the flowers becoming ready to receive pollen a small bulge of tissue, surmounted by a white nipple, is seen emerging

from the tightly packed leaves. This is really the tip of the oval-shaped body contained within the leaves, which is composed chiefly of tissue which will develop into the husk of the mature fruit. Some time after the inflorescence opens it is seen that the white nipple is divided by three equi-distant grooves which meet at the apex. Alternate with the grooves are three bulges which extend right to the

PLATE XII.—COCO-NUT SPATHES.

A.—Includes earlier stages (as above). B.—Also shows later stages, illustrating development of young fertilized nuts.

N.B.—Percentage shed compared with earlier stages.

base of the ovary making it appear globosely three-sided. When the female flower is ripe the pistil is recognizable as a small whitish body, the three short segments at the tip separate and stand erect as three prolongations or teeth, thus exposing the stigmatic surface on which the pollen must fall before the female flowers can be fertilized.

The stigma only becomes ripe or receptive to pollen when the ovules have reached a certain stage of development. The complex series of cell divisions which are associated with this development both in the pollen (male germ cells) and ovules (female germ cells) come within the realms of cytology and will not be

PLATE XII.—COCO-NUT SPATHES

A.—Includes earlier stages as above. **B.—Also shows later stages, illustrating development of young fertilized nuts.**

N.B.—Percentage shed compared with earlier stages.

discussed here. It is sufficient to state that a receptive pistil can usually be recognized by the fact that mature pollen is adhering to it, while there is a shiny, sticky exudate containing sugars and other growth substances present. The pollen

grains readily germinate in this medium and the pollen tube carries the male nucleus down towards the female nucleus where the two elements fuse and fertilization thus occurs. The stigma ultimately turns brown and later black, due to cell collapse, and can be easily recognized as a small, dark rounded area at the tip of the young fruit. The six floral leaves do not develop in size, but form the group of small basal leaves which remain until the mature fruit is ready to drop. The ovary (embryonic nut) has three carpels containing ovules; two of these become abortive and thus finally only one nut develops as is seen in an ordinary coco-nut. In the few cases where two or three of these ovules develop we get bilocular or trilocular nuts as the case may be. Thus the planter can recognize a main reason for twin germination or, in other cases, triple germination in the nursery. This type of nut may produce a palm with two or three stems, which case must not be confused with branched coco-nut palms where the branches come out from a single stem.

On nearly every rachilla (flower branchlet) one, two, three or five or, in rare cases, as many as nine female flowers develop.

Botanists who are interested in a detailed technical and scientific account of the development of the ovule and embryo sac (female elements) of *Cocos nucifera* are referred to investigations on that subject by Juliano and Quisumbung.[34] The following paragraphs of general interest are quoted: "In the development of the ovule and embryo sac of *Cocos nucifera* much time is involved. The internal growth of the axis of the flower must have begun long before the inflorescence has escaped from the outer spathe and ovules are developed after it has escaped from the spathe. The development of the female embryo sac continues and proceeds up to about the receptive stage of the stigma when it becomes ready for fertilization".

Fall of Young Female Flowers, Confused with Nut-fall.

Planters often notice very small female flowers which have fallen to the ground and these are mistaken for young nuts. The presence of such female flowers on the ground is then referred to as nut-fall. Some investigators also assume that it is mainly fertilized flowers which fall to the ground, which, of course, is a wrong premise, as when female flowers fall in the embryo stages this is really a form of "embryo abortion". This fall of unfertilized flowers may be due to causes other than those which are responsible for true nut-fall as, for example, hereditary tendencies, faulty nutrition and so on. It is believed that as far as coco-nut flowers are concerned absolutely no work has been carried out on this important subject. In fact, prior to about 1913, when Fredholm[19] corrected the view, it was customary for coco-nut planters and even some investigators to consider all female flowers even when they were not ripe to receive pollen as fertilized or at least pollinated flowers. Some believed that pollination occurred before the actual opening of the sheath. In other words, the female flower bud was mistaken for the young nut (fertilized ovum).

The young female flower, prior to the pistil being exposed, as mentioned under the description of the female flower, has a superficial resemblance to a young nut. The portion which is seen covering the female flower actually forms the basal leaf rosette at the base of the young nut, so it should not be difficult to correct this view.

Development of Inflorescence or Spathes.

The inflorescence initially begins as a minute protruberance at the axil of the petiole. The practical questions which are associated with the development of the inflorescence and flower structure (floral morphology) and which affect related problems of pollination and fruit setting, may be briefly outlined as follows:—

(*a*) The period from spathe differentiation to flowering and other questions regarding bud differentiation (i.e., first appearance of the primordia), such as chemical changes, have not been satisfactorily worked out for coco-nuts, and this presents a field for research. The conditions essential to spathe differentiation would influence the whole yield of nuts.

(*b*) The period from spathe opening to receptivity of the first female flowers to pollen has been worked out by Pieris[8] in Trinidad, but on a small number of palms only (eight palms about nine years old) and, under their particular conditions, he names the period as varying between 19 and 24 days. Marechal[41] found that this period varied from 9 to 32 days in "Niu Leka", the Fijian dwarf coco-nut, and from 9 to 23 days in Malayan dwarfs.

(*c*) The age or period of growth at which spathes first appear. This apparently varies greatly as, for example, palms come into bearing much later on the heavier soils of Bougainville than on the light soils of the western islands and this period may range from four years in the latter to eight years in the former environment.

It is also fairly conclusively proved that manuring young palms with either complete or nitrogenous manures brings them into bearing earlier. Another question which requires elucidation is whether it is possible to bring coco-nuts into bearing earlier by using substances such as ethylene gas as is done with pineapples in Hawaii. Very close planting is known to delay greatly spathe differentiation which is, undoubtedly, a question of competition for light and nutrients. It is certain that usually the first spathes and the flowers which they bear are abortive. Thus the period of bearing does not commence until some time after the first spathe appearance in young palms. It is a familiar sight to see almost fully developed green nuts fall from young palms and in many cases whole spathes of such nuts are shed. The tendency for this to happen is apparently more pronounced in some young palms than in older ones. The chemical changes which occur at this stage also need working out as they should have a decided bearing on manurial and pollination questions.

(*d*) The interval between the opening of one spathe and the opening of another was worked out by Pieris,[8] on the same palms referred to above, as varying between 25-37 days. This period of roughly one month agrees closely with opinions expressed by various planters here, but more detailed observations are, however, necessary under local conditions as this interval is very variable. According to Furtado[22] a very prolific palm will produce twelve or more inflorescences per annum, or approximately one per month, but quotes records of palms having produced sixteen inflorescences per year. The shortest average interval between successive inflorescences was recorded as twenty days for dwarf coco-nuts in Malaya.[32] Aldaba[4] in the Philippines, from observations on two small palms, shows that the average interval is 25 days. The effect of environment on the appearance of spathes is extremely great even on a single palm and in the

course of a few months. Petch,[45] for example, observing one palm at Peradeniya found intervals ranging from 24 to 58 days. He showed from observations on many palms that the longest interval corresponded with the driest months while the shortest interval occurred in the hot moist months of their wet season. The intervals are governed by many other factors and it is easy to conclude why such differences in behaviour have been recorded even between palms of the same variety. In dwarf palms just coming into bearing in Fiji[1] 1933, the number of spathes produced per palm per annum ranged from 4-15. These palms were very young as it was the second year nuts which were produced. Jack and Sands[32] found that the number of days between the opening of successive spathes varied for—

(*a*) Yellows—18.5 days to 21.1 days.

(*b*) Reds—19.3 days to 24.2 days.

(*c*) Greens—18.7 days to 23.1 days.

The average for a normal dwarf race, therefore, is twenty days.

(*e*) Period of overlap between the male and female phases on the same palm. This refers to whether the male flowers open or not while any of the female flowers on a particular palm are receptive or ready for pollination. This apparently varies with the locality, climate and variety of palms and is a main determinant as to whether palms are liable to self or cross pollination.

Jack and Sands[31-32] claim that the Malayan dwarf palm is normally self-pollinated in Malaya and that the male and female phases definitely overlap. Maréchal[41] on the basis of his experiments shows that this is not the rule with Fijian dwarf coco-nuts, although in this variety he never observed the male phase to end before the female phase began. Working on tall palms, it was found by Petch in Peradeniya[45] that a period varying from three and a half to five weeks was required for the opening of all the male flowers of an inflorescence; that an interval of two to five days then elapsed before the female flowers of the same inflorescence began to open. The female flowers all opened in a period of from one to seven days according to the number present. He naturally concluded that self-pollination was impossible except for the rare occurrence of overlapping of inflorescences in the same palms. Information gleaned in Java indicates that there the female flowers are usually receptive about one week after all the male flowers have disappeared. According to Jack and Sands[31] coco-nuts behave differently in the warm humid atmosphere on the lowlands of Malaya. There the length of duration of the male phase is curtailed, while the duration of the female phase would appear to be longer in both tall and dwarf palms. The most striking fact is that the female phase, not only begins, but most frequently ends before or at the same time as the male phase thus rendering self-pollination the rule, instead of being an occasional chance occurrence. The average duration of the male phase in dwarf palms eight years old was 21 days with a variation of from 15-24 days, and that of the female phase was eight days. On Witu the author found in tall palms several male flowers open on spathes containing young female flowers which were practically ready for receiving pollen, although on other spathes with receptive female flowers the male flowers had entirely disappeared. This is probably a variable characteristic which may be hereditarily transmitted. This question requires much more detailed investigation as far as New Guinea is concerned.

(*f*) The question of overlapping appearance of male flowers on one spadix and female flowers on another spadix of the same palm. It appears that this rarely occurs, although it would be a valuable genetical characteristic if present.

(*g*) Profuseness of male and female flower production. It is a well-known fact that the first spathes which appear on most palms have a tendency to produce male flowers only. It is known also that there is a decided tendency for some palms to produce female flowers only, and for others to produce male flowers mainly at all stages of growth. These are probably hereditary characteristics which may be temporarily influenced by changes in environment such as excessive drought. The male flowers always exceed the number of female flowers present in any spathe and may range from a small number to thousands, depending largely on the branching of the spadix and the length of the branches which carry them. The dying off of the spadix branches from the tip is a common phenomenon where soil conditions are unfavorable and in this way, the numbers of male flowers present are greatly reduced. The female flowers are produced in much fewer numbers, and are always produced towards the basal portions of the floral branchlets. One has only to look at any plantation to observe individual tall palms carrying some hundreds of small nuts and naturally such palms carried large numbers of female flowers in the first instance. The profuse fruiting of the Malayan dwarf coco-nuts is another example of heavy female flower production. Frond choked or poorly vigorous palms carrying no female flowers at all are often seen and these represent the other extreme of shy production. All investigators have indicated the wide variability of female flower production. Furtado[22] states that the number in a spadix may vary from zero to over 300, depending on the strain, treatment, &c.; whilst Sampson[52] records having counted up to 235 flowers on one spathe and that frequently there may be from 100-200 flowers present. In Fiji,[1] on crossed dwarf palms just coming into bearing, it was found that the number of female flowers per spathe ranged from three to 62. Pieris[46] made counts on 215 inflorescences in Ceylon and obtained a range of variation of from one to 92 female flowers. He presents a table which shows that the frequency distribution is very symmetrical, and that more than 94 per cent. of the observations lie between the limits of none to 44 flowers. Very little correlation was found between the number of branchlets in the inflorescence and the number of female flowers. In Malaya[32] the number of female flowers per spathe carried by various dwarf palms was found to be as follows:—

Greens, 21.4; yellows, 13.6; reds, 10.6 in three years' observations.

(*h*) Periodicity of flowering and consequent bearing as related to season. As stated before, there is evidence of the spathe production being related to season in Ceylon; Sampson gives detailed records and a graph showing that there are very definite seasonal fluctuations on the coast of India, and suggests a correlation with climatic conditions, but very prolonged and detailed records are still necessary to determine this point precisely. Maréchal[41] records a tendency for Malayan dwarf coco-nuts in Fiji to produce more female flowers in the inflorescences which open from November to March than in those opening during the rest of the year. The question of periodicity of bearing and alternate bearing as related to hereditary and environmental conditions needs much more work.

The Nut.

Planters are all familiar with the structure of the coco-nut, which has also been described many times in books on the subject (*vide* Sampson and others). Botanists in general regard the fruit of the coco-nut palm as a "drupe" and not a nut, as the term so widely used applies. It consists of a smooth, tough, brownish to greyish epicarp (the smooth surface); a fibrous, mottled, brown mesocarp (husk), and a hard, thick, brown endocarp (shell) within which is the endosperm (kernel) enclosed in a closely adhering testa (skin).

Juliana[35] has written a careful technical account of the origin, development and nature of the stony layer of the coco-nut as well as an account of the development of the spadix, the female flower and the fruit. It is not proposed to deal further with the morphology of the fruit here, as detailed accounts are readily available. It might be pointed out, however, that long before the time of fertilization the endocarp (developing stony layers) is already differentiated as a soft, creamy white structure surrounding the loculi.

Age of Bearing.

The age at which palms come into bearing is definitely variable, and is largely correlated with soil and climatic conditions. Strain also does have a decided influence in determining at what period young palms reach the bearing age.

In any young plantation it is seen that certain palms come into bearing much earlier than others. As for example, it is seen at Keravat that certain young tall palms, not more than three years old, have thrown out spathes and are bearing young nuts while the surrounding palms in the same area show no evidence of fruiting whatsoever. It is this variation in maturity which should allow of the isolation of early maturing strains such as is mentioned in the section dealing with coco-nut breeding. Dwarf palms usually begin to fruit in their third or fourth year and reach their best at about the fifteenth year. A tall palm usually commences to fruit somewhere about the fifth year, and probably reaches the stage of maximum production in about the 20th to 30th year. The stage at which palms come into bearing here and reach their maximum production is very variable, as palms grown in the light coral soil of the western islands commence fruiting earlier, and go off earlier, than palms in the heavier soils of Bougainville Island. On heavy soils palms often do not commence fruiting until about their eighth year, which means that the period when they come into profitable production is around the twelfth year. Many palms growing on soil-exhausted areas here are definitely over their stage of maximum production before their 40th year. Palms 60 years old under favorable circumstances show no sign of falling off. How long they remain fruitful is not known, but it more than exceeds the century mark.

Palms which are closely planted, such as in native groves, are often ten or twelve years old before they commence bearing properly. All other things being equal, the sooner the palms come into bearing the less cost is involved in bringing a plantation to the bearing stage, which is a most important consideration.

Palms coming into the stage of maximum maturity have been noticed to suffer a physiological setback, and this has been seen in scattered parts of New

Guinea on several occasions. This often affects the production for two years. This condition has also been reported from Malaya, and is most prevalent on certain types of soil under particular climatic conditions. This occurrence has been mistaken by certain planters for a new disease. It must be remembered that palms reaching the bearing stage are at a physiologically critical period. The fruiting places an extra strain on the plant, which becomes apparent when the conditions are not entirely favorable. The character of the soil and the care bestowed causes very pronounced differences in the development of the young plants, which, in turn, influence the time at which the palms come into bearing. At six to eight years is quite a reasonable time to expect the palms to produce their first crop of nuts for copra production, and at about ten years they should reach the stage of profitable production.

The following report on Orangerie Bay Government Plantation, by Staniforth-Smith, in the Papua Annual Report,[44] supplies very good figures on a plantation coming into bearing. "The area of 591 acres planted between 1912 and 1914 yielded this year (1923-24) 238 tons of copra, or slightly over 8 cwt. per acre. The area of 529 acres planted between 1914 and 1918 was then coming into profitable bearing, and yielded 35 tons of copra. The estimated yield for 1924-25 is 300 tons."

——	1917–18.	1918–19.	1919–20.	1920–21.	1921–22.	1922–23.	1923–24.
Acreage collected from ..	74	350	500	600	600	600	680
Nuts per tree	1.6	9	13.5	16	28.1	42.3	37
Copra per acre in cwt. ..	..	2.92	2.96	3.6	6.07	7.66	8
Nuts per ton	..	5,002	5,132	5,034	5,181	5,484	5,160
Tons of copra	.3	17.35	74.17	109	182	230	273
Total number of nuts, 1,000's	6.6	167	379.8	548.6	943	1,261.3	1,408.7

Natural Nut Setting.

The percentage of flowers forming mature nuts is governed by all the cultural and environmental factors which affect the growth of the palms, such as climate, cultivation, &c. The question of hereditary variations in the number of mature nuts produced by coco-nut palms has been dealt with in discussing seed selection.

In addition to the general condition of the palms the factors governing cross-pollination and cross-fertilization greatly influence the proportion of mature nuts set compared with the original numbers of flowers produced, and require elucidation.

As late as 1929 Cheeseman[8] indicated that the information available as to whether palms producing numbers of female flowers necessarily set a large proportion was limited to a statement by Sampson to the effect that some trees never produce a large number of female flowers, but at the same time set a high proportion of them. The result is that the cropping is relatively steady, whilst other palms are very irregular in bearing. Since that time, however,

Pieris[46] having noticed that the number of female flowers on the inflorescence varied within wide limits, calculated and showed that the number of ripe nuts produced showed a definite positive correlation with the number of female flowers produced. This was not so high, however, as would be expected (+0.64). He showed that for fairly small numbers of female flowers, say, below 50, the correlation is fairly close, but for larger numbers of female flowers the numbers of nuts produced are not always correspondingly high. He concluded, however, that it would be safest to select palms whose upper immature inflorescences display the largest number of buttons. Sampson says that fruit is properly set about 50 days after the flower has faded.

It has been mentioned elsewhere that the number of nuts borne to maturity depends on several factors. A number of young nuts fall due to competition for nutrients, or because of lack of fertilization altogether. Lever and Phillips[38] showed during their work in the Solomon Islands on the relation of the "Amblypelta" bug to nut-fall that 70 per cent. of the nuts fell in cases where the insect was included, which means that approximately 30 per cent. of the nuts matured. They also found that the natural nut-fall in the field was estimated at two-thirds of the number of female flowers present, which closely agreed with the ratio obtained inside cages which were designed to exclude insects only. It can be calculated from figures given by Pieris in Ceylon[46–48] that he obtained an average of a 34 per cent. natural set, which agrees closely with the results obtained in the Solomon Islands. In his experiments the mean number of female flowers present in 236 cases was 20.92 per spathe, which set an average of 6.8 nuts (34 per cent). One of the highest percentage sets recorded was where one spathe with 28 female flowers set 25 nuts (nearly 90 per cent.), while on the other extreme 84 female flowers set three nuts, or 3.5 per cent. approximately. The highest number of female flowers to be recorded on any one spathe was 116.

Sampson says that "normally the number of female flowers which set will be about 25 per cent. of those present in the first instance, while it may rise to 50 cent. in the case of trees which form a large proportion of fruits. On 25 trees figures showed that the percentage of nuts set to female flowers present varied from 9–34 per cent. according to season, with a general average of nearer 20 per cent." In crossed dwarf palms in their second year of bearing in Fiji,[1] it was found that the percentage set of female flowers ranged from 10 per cent. to 100 per cent., while the final percentage of mature nuts which resulted was from 7 per cent. to 9 per cent. These results are hardly comparable with what would occur on mature palms; further, it was found that the coco-nut spike moth *Tirathaba trichogramma* was present and destroyed from 0 per cent. to 17 per cent. of the female flowers on individual palms.

Jack and Sands[32] made the following observations on the natural setting of dwarf palms: "The percentage of fruits to flowers remaining at two (2) months was for 'yellows' 38.90 per cent., 'reds' 53.2 per cent., and 'greens' 26.4 per cent. Subsequent losses of fruit amounted to 5.7 per cent., 5.4 per cent. and 4.2 per cent. only, respectively. The high percentage of infertile flowers was not due to insect injury, but rather, it is thought, to imperfect pollination or absence of viable pollen in unfavorable weather. It is possible that the failure of the development of a certain number of young fruits may be physiological."

The setting of a standard for a good percentage of nut setting compared with the number of female flowers present on any series of coco-nut palms is difficult to establish owing to variations caused by season, environment, &c. Owing to the relatively few female flowers present on most spathes a satisfactory percentage natural set of coco-nuts should apparently be high so as to provide a satisfactory yield, e.g., between 20 per cent. and 35 per cent. This indicates that optimum pollination conditions are very important; and also where palms are suffering from chlorosis, soil exhaustion or bad drainage, this percentage would be greatly lowered. If it is assumed that the comparatively large number of 200 female flowers is present, and that such a satisfactory percentage of, say, 30 per cent., flowers set was obtained, this would mean that 60 nuts should be carried to maturity. This calculation gives some idea as to why heavy bearing palms are in the minority and selection is necessary.

Agents of Pollination.

Petch stated[45] "that coco-nuts depended on cross-pollination by insects, and probably also by the wind." He considered that bees and hornets, which feed greedily on the honey produced by both the male and female flowers, were the chief visitors to the coco-nut flowers. He said that "the ubiquitous ant, though it revelled in the nectar of flowers, was unlikely to assist in cross-pollination, or even to have access to the pistil of the female flower at all, thanks to the natural protection afforded by its ring of nectar at the receptive period." It must be commented here that ants do not always visit flower spathes to collect nectar even during the receptive period, but also to collect the honey dew secreted by species of mealy bug and aphids; at least that is the case in New Guinea. (*See* also Furtado's[22] remarks.)

The late W. W. Froggatt in 1911[20] makes the following reference to insect visitors to coco-nut flowers: "The coco-nut appears to be comparatively free from destructive insects when flowering and fruiting, though when the male flowers burst into bloom they attract a number of flies, bees and wasps; but these are more beneficial than otherwise, as they help to distribute the fine, dust-like pollen from the male spathes to the female spathes, and aid in their fertilization."

On the question of natural pollination Maréchal[41] agrees with other workers that both wind and insects play a part, but regards bees as by far the most important pollinating agents as to be essential for high production of nuts. The role of bees is still highly questionable under New Guinea conditions, hence it is seen that more local experimentation is desirable. According to Furtado,[22] Jepson, who paid special attention to insect visitors to coco-nut flowers in Fiji, had earlier expressed the same opinion and attributed the dropping of female flowers in many districts to insufficient insect visitors. He noticed that the yield was heavy on estates where bees were present in large numbers, either owing to artificial rearing or otherwise, and recommended planters to introduce bees to their coco-nut estates.

Sampson[52] says that fertilization is largely done through the agency of bees, but there are many other insects which visit the female flowers for the sake of their nectar but which do not bring pollen at the same time. He believes that ants are harmful to pollination, as they drive off the bees, many of which

are small and stingless. Among the ants was specially mentioned the red ant *Oecophylla smaragdina* (common Kurukum here) as being harmful in preventing the female flowers from being fertilized, where they live on mealy bugs and build nests preventing the entrance of other insects.

Several investigators[4, 8, 22] admit that there is decided possibility of ants acting as pollinators. Furtado says that "in Singapore unlike Peradeniya the nectar secretion is not in sufficient quantities as to exclude the ant from the work of pollination and they may self-pollinate where the male and female phases overlap." Owing to the fact that ants move so slowly from palm to palm they are not liable to have much effect in cross-pollination, but are likely to upset studies on self and cross-pollination on the same palm, as they are not easy to exclude.

Pieris, according to Cheeseman,[8] tried to assess the relative importance of the natural pollinating agents and to separate the effects of wind, crawling insects (red and black ants) and flying insects. The flying insects be observed in the inflorescences were *Apis mellifica, Musca domestica* [both relatively scarce here.—*Author*], *Polistes annulatus,* and a small black beetle. These were easily excluded by bagging emasculated inflorescences with coarse muslin, which would not interfere seriously with wind-borne pollen. The separation of wind and small crawling insects was found much less easy as, even with fine-grained muslin tied around the base, wind-borne pollen was not entirely excluded. In the fine-meshed bags a 6 per cent. set was obtained, which was said to be probably due to the imperfect exclusion of wind-borne pollen. Pieris concluded that wind pollination can only be as effective, as in this experiment, at fairly close quarters, as did Aldaba in the Philippines.[4]

He repeated Aldaba's experiment of exposing vaselined plates in different positions to catch wind-borne pollen, and where the source of pollen was only three trees away only three or four grains of pollen were collected.

Cheeseman (*loc. cit.*) sums the position as follows: There is a general agreement that both wind and insects play a part, and that wind is only effective at fairly short range. Further, there is a striking similarity between the lists of insects observed visiting flowers in different parts of the world. All observers place bees at the head of the list in importance and add *Hymenoptera*. Also the common house-fly, or closely allied species, and at least one species of beetle, are reported, but little importance assigned to them. Jack and Sands[31] believe that wind is the main factor in coco-nut pollination in the Malay Peninsula, and that insects appear to play an unimportant part. Although numerous insects,[1] more particularly bees, visit the male flowers to collect pollen and nectar, few appeared to be attracted by the female flowers situated near the bases of the branchlets of the inflorescence. Their statement concerning wind pollination follows: "When coco-nut flowers are in full bloom at about 10 a.m. when the dew has dried up, and when the gentle breezes frequently begin, clouds of pollen can be seen floating away in the sunlight. In a very slight breeze these pollen clouds do not travel far owing to the weight of the pollen, but it is highly probable that with the strengthening of the breeze as the day advances the pollen clouds are carried to considerable distances, and thus cross-pollination is effected."

The question of wind velocity as effecting distribution of pollen is a very important one, because plants which have fully entomophilous flowers, such as apples or pears, may have their pollen carried over 100 yards in heavy winds. Other investigators state that, although the structure of the inflorescence apparently favours wind pollination, the presence of nectar glands in both male and female flowers, as well as the suture in the pollen grains, suggest insect carriers. Male flowers possess three nectaries at the base of the teeth which crown the central column, and the stigma, or receptive surface, of the female flowers also furnishes nectar, so that the visits of insects to both types are assured.

If the flowers are adapted to efficient insect pollination only, it is hardly likely that such large quantities of male pollen would be produced over such a long period. Various grasses and crop plants, such as maize, which are mainly adapted to wind pollination, also secrete sugary solutions. Thus arguing on analogy is not altogether sound.

It is, as Cheeseman says, that the coco-nut flowers are adapted to pollination by both wind and insects, and possibly birds. The appearances are that some agencies are more active in some countries than in others. Except for the Dammar bees, *Melipona praeterita* Wlk., there is not a large bee population which visits coco-nut flowers here. As far as New Guinea is concerned, the question needs detailed investigation.

Insect Visitors to Coco-nut Flowers in New Guinea.

So far no detailed work has been carried out on this problem here, and investigations on this subject are required. As the identification of insect visitors to coco-nut flowers is more in the entomologist's field, Mr. J. L. Froggatt, Entomologist,[21] was able to name some insects likely to visit coco-nut flowers in New Guinea. It needs caging trials and microscopic examination before the relative ability of these insects can be accurately determined. Insects which visit flowers may be beneficial where they act as pollenizers, or they may be casual visitors only, while in the case of others, such as *Axiagastus cambelli,* they can be injurious to them. It appears fairly certain, however, that the small native bees *Melipona praeterita* Wlk. are amongst the most frequent insect visitors to coco-nut flowers here. These small bees commonly fly on to one's skin or hair, and may be recognized as a tenacious little insect, although they do not sting, and are known as the "dammar bees" in Malaya. Although several genera of the family *Apidae* are present, bees of the genus *Apis* (or types closely related to and including the hive bees) are apparently not common in this Territory. Such genera of this family as *Crocisa spp.* and *Megachile spp.* are more common, but their relation to coco-nut flowers, if any, is not known. Amongst the various flies of the order *Diptera* present are the following: *Syrphidae* or hover-flies (several species), *Sarcophaga spp.* (these are large, striped flies, mentioned by Aldaba as being useful pollinating agents in the Philippines), and *Muscidae spp.* (especially *Lyperosia exigua* de Mey). These families and genera are the most likely to contain any efficient pollenizing insects here.

Some wasps of the order *Hymenoptera* may be found to be pollenizing coco-nut flowers here. *Polistes annulatus* has been mentioned by Pieris[8] as being an effective pollenizer on coco-nuts in Trinidad. There are several species

of these Vespid wasps in New Guinea, such as *Polistes lepidus* Sauss and *Polistes bernardi* le Guill, but their efficiency as pollenizing agents here is not known. Wasps of the genus *Vespa* are said to visit coco-nut flowers in the Philippines. A large reddish-brown wasp of this genus is also commonly seen on coco-nut flowers here, but usually they are not plentiful, though they appear to work quickly and efficiently.

Two small unidentified species of wasps (apparently Thinnids) appear to be the busiest pollenizers at Keravat plantation. Mr. Froggatt has recorded several beetles of the family *Cetonidae* as visiting coco-nut flowers here, but, as they are pollen feeders, there is also the possibility of their being pollenizing agents. The green beetle, *Lomaptera batchiana* Thoms, is a very common visitor to coco-nut spathes in New Guinea. *Poecaliphyra emilia* White, a small green beetle, has also been recorded several times on coco-nut flowers here. Many other beetles have been caught on coco-nut spathes, but are doubtless casual visitors.

Axiagastus cambelli Dist., the stink or flower bug, family *Pentatomidae*. This insect may, in addition to destroying blossoms by sucking sap, act as a casual agent in pollination. It must be conceded that they move slowly from one palm to another, and are more liable to do harm than good. One company here, in the belief that ordinary hive bees may assist nut-setting, made extensive introductions of ordinary hive bees, *Apis mellifica*, and Italian bees to the majority of their plantations. These did not survive, and this was said to be due to the depredations of wasps and other insects present. Despite the absence of hive bees here, coco-nut flowers do pollinate and set entirely satisfactorily, and it is decidedly doubtful whether bees would increase the set. However, this could only be satisfactorily determined by caging experiments.

OTHER AGENCIES OF POLLINATION.

Knuth[36] has stated "that the coco-nut is pollinated through the agency of wind"; but quotes Father Dahl, who noticed the birds *Charmosyna subplacens* Scl. [a small lorrokeet.—*Author*], *Cinnyris frenata* S. Mull. and *Cinnyris corinna* Salvad as the frequent visitors to flowers in the Bismarck Archipelago. Reference to Father Meyers' book[42] indicates that these two latter species belong to the Blumensauger (lit. blossom sucker) known in English as sun-birds, belonging to the family *Nectariniidae*.

Furtado[22] says "that *Anthreptes malaccensis* is the sun-bird, which is almost invariably associated with coco-nuts in the Malay Peninsula, and various other birds were seen in the vicinity of coco-nut inflorescences, but it must be borne in mind that even these birds, which possess especial adaptations in their beak for extracting nectar from various kinds of flowers, often visit them for the purpose of capturing insects for their prey. He concludes that, where there are insects such as bees to pollinate the flowers, their ability is, like the wasps, doubtful." There is no experimental evidence to disprove Father Dahl's original assertion as far as New Guinea is concerned, and it is the author's opinion that in certain parts of New Guinea birds do play some part in coco-nut pollination, though this may be as an adjunct to wind and insect agencies. The very size and shape of the female flower suggests the possibility, as does the fact that nectaries are present in both male and female flowers, which they are adapted to suck.

Bird Pollination at Meto, Witu Island.

On Saturday morning, 16th October, 1937, and again on the following Monday and Tuesday, it was noticed at Meto that a small sun-bird, with the local native name Pitchu or Peetshu, was present in large numbers in the flowers of the coco-nuts, both in the mornings and in the afternoons. Slightly larger lorrokeets were also seen to visit the flowers, but not so frequently. Natives present on the plantation from other parts of New Guinea all recognized these birds as belonging to the flowers, and said that they were common almost everywhere, such as in the Bismarck Archipelago. It was noted that the birds move quickly from palm to palm, and, being small and flying at a height, the large numbers present were not noted until a special look-out was made. Once notice was taken of their movements, it was found that practically every spathe observed was visited every few minutes, and often more than once in that time. Thus, assuming that these birds are capable of acting as pollen-carriers, the frequency of their visits was sufficient to enable them to act efficiently as pollenizers, especially as they could visit a great number of flowers in one day. It was also observed by the acting manager, Mr. Whitehead, in company with the writer, that these birds were active from early morning until 5.30 p.m., which is similar to what happens with bees in temperate zones. They usually fly only short distances at a time, and appeared to move about in a series of short flights and thus visit many palms in a relatively short time. They usually crawl all over the spathes, either male or female, before flying to other palms close by. In many cases they fly to the spathe and hang underneath the floral branchlets by means of slender, prehensile claws, and sup the nectar with their forked tongue and finely-hooked beak. Thus pollen should easily be shaken on to their ventral surface, while their back feathers are also in contact with the lower branches. The birds also crawl over the flowers and come in close contact with them in this manner. Their beaks are very finely pointed, and the tongue is a marvellous adaptation, being extensile, long, flattened and forked at the tip with a terminal brush.

A large, new spathe, which had just been visited by some birds, with the male flowers just opening and the female flowers not nearly receptive, was cut down and examined. It was seen that, apparently, they had not damaged the male florets in any way, and that some pollen present was mature. It was thus thought likely that these sun-birds may be important pollenizing agents at Meto, more especially as they confine a good deal of their attentions to young spathes. A native boy was deputed to shoot some of these small birds while actively at work on the palms. At about 8.30 a.m. a male bird was shot on a female branchlet. The bird actually did not fall from the spathe, and it was found that one of the main feathers was closely pinned to the flower stem within 1 inch of the receptive pistil (covered with moisture of syrupy consistency). On this spathe the male flowers had disappeared. A preserved specimen of this branchlet was taken with the feather still adhering. About half an hour later another bird (female) was shot, and this one was attached to a spathe with a few male flowers, while the female flowers present were not yet receptive. In this case, also, distinct confirmation of the activities of this female bird was obtained, because when the bird was shot the blood was actually scattered over the anthers still shedding pollen in male florets, showing where the bird had been attached.

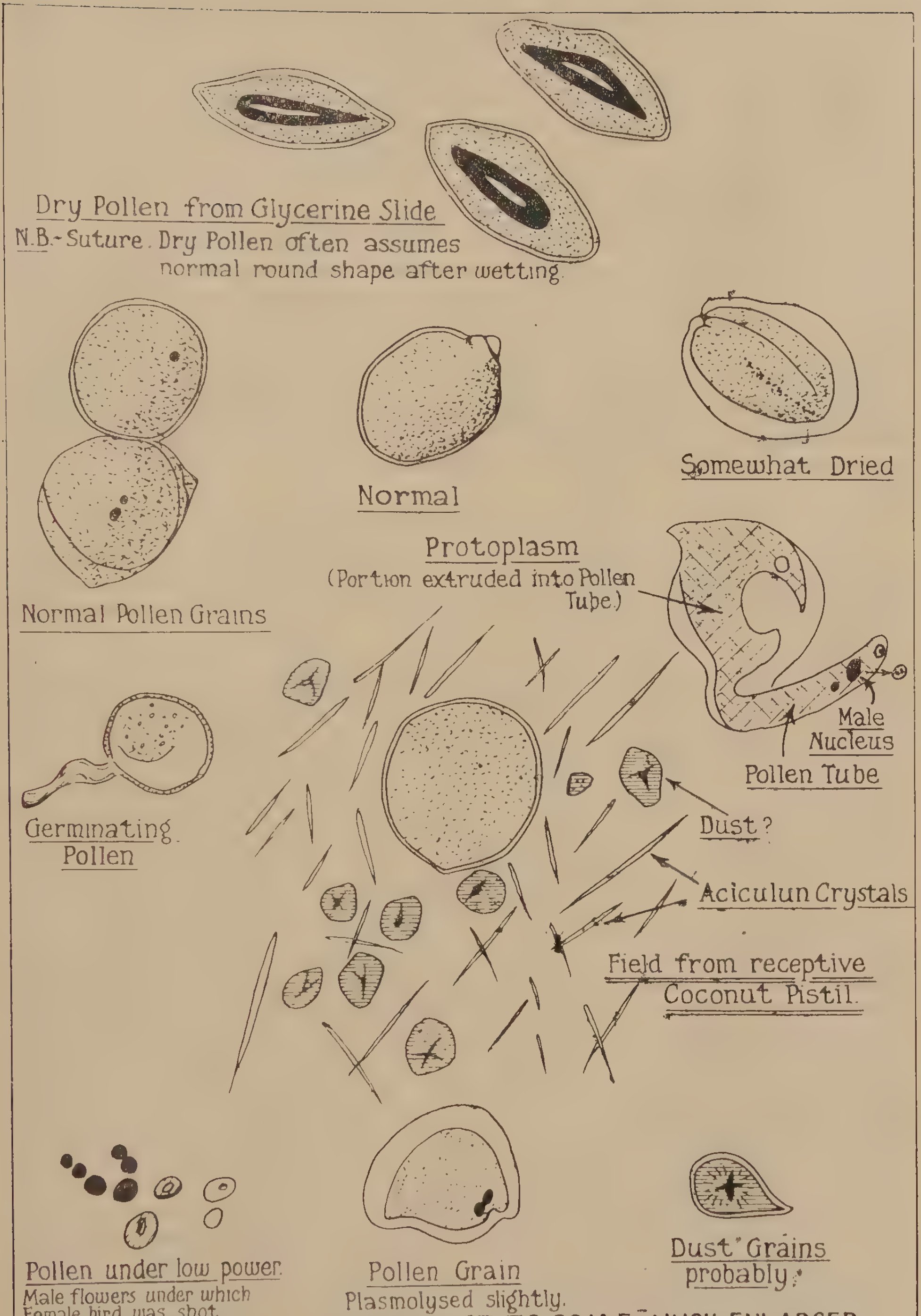
It should be noted that on the spathes examined only *Oecophylla* (Kurukum ants) and mealy bugs were present. Other active insects were noticeably absent. Unless ants are more useful than is admitted elsewhere, insects must have been responsible for very little of the pollination occurring at this period in the particular plantation. These birds, although present in New Britain, have not been seen in large numbers such as was the case at Meto.

Microscopic Examination.

To prove whether any transference of pollen had occurred it was necessary to examine the feathers for pollen, and it was apparent to the eye that some was present on the male bird. A small microscope was available at the plantation, and this enabled some interesting observations to be made despite the limited facilities. Feathers from the male bird were taken and a slide made from the dust on the wing. Odd pollen grains were observed in this dust, and also on the feathers when a separate examination was made. It was not so plentiful as would be expected, as the feathers of both the male and female birds are apparently ideal for holding pollen. The small pinnae of the feathers which form the blade have distinct epidermal serrations, due to the peculiar compressed structure of the cells of which they are built up. The interlocking edge of these serrations appear well suited for pollen-carrying, especially where they are so finely divided, as in this particular bird. Both the back (dorsal) and front (ventral) feathers are short and as soft as down. Such a structure would act almost like a powder puff. New pollen was actually obtained from receptive pistil on the female flower where the male bird was shot, together with some acicular crystals and some dust in the same field (*see* rough drawing of fluid). Some of the grains seen may have been dried-out pollen. Much pollen was also seen on the outside surface of the button, showing that a good deal of pollen had been transferred to this particular pistil. The pollen seen on the birds was compared with pollen taken direct from fresh male flowers, and they appeared very similar. The possibility of this bird acting as a pollen-carrier was thus definitely established, and the chances are that the birds described are responsible for a considerable amount of cross-pollination on Witu Island, and may act similarly in other parts of the Territory. It was noted that the wind was only strong at odd times during the time of the observations at Meto. There was however, some rain at intervals which on one afternoon was accompanied by strong winds. A rather lengthy description of these birds as pollen-carriers was given only to show how much more it is required to know about the subject. Most investigators agree that wind pollination is the main factor in cross-pollination of coco-nuts, and without necessary experimental data this concurs with the writer's opinion, also. Insects, birds and other agencies may have decided utility for pollinating coco-nut flowers in periods of calm weather.

Identification of Birds at Meto.

The following is a short description of the birds under observation. Specimens were taken for identification. Both the male and female birds are really light and small, being about the same size as a diamond sparrow. Birds are less than 3½ inches long, and are provided with a long slender pointed beak, slightly hooked and shiny black at the tip.



COCONUT POLLEN · DRAWINGS NOT TO SCALE - MUCH ENLARGED.

Beak and tongue are specially adapted for sucking nectar. Legs are grey and yellow, with slender prehensile claws. Male bird is darker in colour than the female, and has a large red splotch on the throttle (ventral surface), while the crown of the head is black. It has a general greenish-yellow sheen, especially on the back overlying the darker colour. The body appears more slender and is not so fluffy as that of the female. Nevertheless, in both, the feathers on the back and ventral surface are short and soft. The female bird is plumper in outline, and almost wholly coloured grey. It has a lighter greenish-yellow sheen, especially bordering the tail attachment. Tail feathers are shorter, and there is no reddish splotch on the throttle, except for a reddish tinge which develops on old female birds. Specimens have been identified by the ornithologists of the Australian Museum as follows:—

"The specimens are male and female of *Myzomela sclateri* (Sclater's Honey-eater). The genus (family *Meliphagidae*) has many New Guinea species, and is also found in Australia. The species of *Myzomela* superficially resemble Sun-birds (family *Nectariniidae*), which range from Africa and Southern Asia to New Guinea and Australia. In the *Meliphagidae* the tongue is extensile, forked at the tip, and has a terminal brush, but in the *Nectariniidae* it is tubular and has no brush."

Problems of Pollination and Fertilization.

The importance of pollination studies to plant-breeding of coco-nuts is discussed in conexion with that subject. Investigators on pollination problems necessarily differentiate between pollination, fertilization and fruitfulness (or production of mature nuts).

Pollination refers to the actual transference of pollen either to flower pistils on the same palm (self-pollination) or to flowers on other individual palms (cross-pollination) by any agency whatsoever; which, simply stated, means transference of viable pollen grains to the stigma. Fertilization refers to the actual union of the male and female nuclei, or elements, carrying the hereditary determiners, after the pollen tubes have grown down the pistil and reached the ovule. This does not necessarily mean that fertilized young nuts will develop to mature fruits, but it does pre-suppose pollination of the pistils. Fruitfulness refers to the capacity of the palms to produce fruits, or in this case coco-nuts. It is obvious that not all fertilized flowers develop to mature nuts, as is recognized by the extensive study given to the problems of nut-fall by various investigators. The reader is referred to a detailed discussion on this subject by the present author.[16] There is also an hereditary tendency for some palms to produce nuts without any fertilization at all. Such palms are known in all countries where coco-nuts are grown and are familiar to some of our local planters as the so-called male or seedless coco-nut palms. These usually develop a long spindly nut with no embryo and little kernel, though they might hang on until quite dry and shrivelled. This undoubtedly represents a form of "parthenocarpy" or vegetable development of the nuts. Much work remains to be done to determine accurately what outside factors such as temperature, moisture, humidity, and hours of sunlight are really optimum for pollen germination, pollen tube growth and fertilization. This means that accurate recording with continuous recording instruments, such as thermographs and hydrographs, should be carried out while any pollination investigations are being made. The fact that coco-nuts bear so well close to the seashore or at low levels suggests

that moving, warm air of high humidity may provide the optimum conditions. Prolonged dry weather or too much rain at the time of pollination may be unfavorable for pollen germination.

After drying out longitudinal sutures appear on the pollen grains and they assume an elipsoidal shape instead of the normal round shape of turgid pollen (*see* rough sketch). Such dried-out pollen grains when moistened assume a normal round shape, and such alternate drying out and moistening may happen more than once. This suggests an adaptation which would keep the pollen viable until sufficient moisture was available (e.g,. on the pistil) for proper germination or during the time it is being disemminated through relatively dry air.

Maréchal[41] and Pieris[8] have shown that pollen may be stored for about a week without special precautions, but it can be stored for many days under dry conditions, such as in a desiccator, over sulphuric acid, or in gelatine capsules. The former found that 35 per cent. to 60 per cent. retained their vitality for sixteen days over 30–40 per cent. sulphuric acid, while the latter found that after eight days loss of viability occurred, but was able to get a 4 per cent. germination on the 31st day in pollen from gelatine capsules. In each case 25 per cent. sucrose (cane sugar) solutions were used for the germination studies. It is certain that a high humidity favours pollen germination, but a low humidity favours retention of viability by the pollen.

Both Pieris[8] and Aldaba[4] have found that all coco-nut pollen samples examined show the presence of varying proportions of shrivelled and small abortive pollen grains, and the writer has also observed these. The presence of such sterile pollen grains has also been seen by the author in temperate crop plants such as lucerne. The amount varies with the individual plant, and can be explained on the basis of East and Manglesdorf's conception of inhibiting, hereditary factors.[17] Such pollen sterility lessens the chances of nut-setting by self-pollination, and emphasizes the importance of cross-pollination to the natural economy of such plants as coco-nuts.

The period during which the female flower remains receptive apparently varies in different places. According to Furtado,[22] in India, and Petch,[18] at Peradeniya, this period is about 24 hours, while it was shown by Aldaba,[4] in the Philippines, and Furtado,[22] working at Singapore, that it lasts two or three days. No work has been done on this aspect in New Guinea. As far as one can judge, no one has yet determined whether coco-nuts have an optimum time of the day for pollination, except for general statements that it is about 10 a.m. or from 8.10 a.m. Most crops display an optimum period, as for example pumpkins only pollinate early in the morning, while in Australia oats pollinate best in the early afternoon. In New Guinea, coffee pollinates best in the morning between certain hours. It is probable that there may be some such defined period with coco-nut flowers, and, if it is in the morning, as is indicated, then rain in the afternoon would have little effect on pollination. Sampson says that "when the flower is about to open the stigmas swell, turn white in colour, and when the flower actually opens they expose a sticky, viscous surface in the tri-radial opening. They are then receptive, but apparently do not remain so for long, as they have a strong scent in the early morning which soon passes off in the heat of the day. The scent is distinct and apparently designed to attract insects."

In the flowers of most plants, liable to cross-pollination, there is a differential rate of pollen tube growth where a pistil is fertilized with pollen from the same flowers compared with the rate of growth of foreign pollen placed on the same stigma at the same time. Thus while a stigma may receive pollen from the anthers of male flowers on the same inflorescence or flowers, it grows more slowly than the foreign pollen and self-pollination is not so likely where foreign pollen is present.

It is not generally realized by laymen that different grains of pollen from the same flowers, on any individual trees, display differential hereditary capabilities as to length of pollen tube growth in the same way as tall and dwarf palms may appear. The pollen tubes must grow a certain length down the stigma to carry the male nucleus to the female nucleus in the ovule, or egg, and often only a proportion of the pollen grains which reach the pistil are capable of doing this. This is further complicated by the fact that inhibitory factors are commonly present which may partly or completely retard pollen tube growth. This is a brief attempt to explain a technical subject which needs more attention from professional investigators in carrying out coco-nut pollination work.

Selection in the Nursery.

This side of coco-nut planting receives insufficient attention although it is practically as important as the original selection of the seed nuts and should not be neglected. It is very poor economy to place insufficient seed nuts in the nursery so as not to provide for the rigid selection of only good type and vigorously germinated seedlings which are strong, sturdy and healthy. To allow of the rejection of inferior types and non-germinated nuts and to replant misses in the field, more than 60 to 80 per cent. in excess of the nuts actually required to plant a certain area should be set out in the nursery. This may seem costly and unnecessary on first appearances, but, when the non-germinating or weakly viable nuts are rejected and also the unhealthy or off type seedlings are put on one side, the precautions and cost of laying down the extra quantity of nuts are fully justified.

The planter must remember that these nuts are the products of cross-fertilized flowers and, regardless of the outside appearance of the nuts, the seedlings derived from any one palm will display considerable variation and some palms will tend to produce much stronger seedlings than others. Long rangy plants or those having any tendency to yellowing or chlorosis should be avoided. Plants with long, slender leaf-stalks and long, narrow leaf-blades, i.e., "leggy" seedlings, should be discarded as unlikely to produce profitable trees. Similarly, those seedlings which have any tendency to twisting or any hereditary abnormalities should not be used, while any sickly or weak young plants should be rigorously discarded. Bad seedlings can never produce strong, healthy palms.

Where selection of seed nuts is being made from marked trees, or for inclusion as a population in a breeding programme, it is as well to know that there is a tendency for the nuts from some palms and even from some localities to germinate badly. This is a variable characteristic which is probably more often transmitted than not. Of course the presence of nuts which had grown to maturity without proper fertilization would give the same effect but this may also be an hereditary trait peculiar to the particular palms.

It is also found that the nuts which germinate first usually give the best seedlings. Pieris[49] says that "plants which germinate tardily produce equally tardily in the fields". Smith[56] in Malaya carried out germination trials with 500 heavy nuts, all over 575 grammes in weight, derived from 66 palms; the tabulated differences in behaviour between populations from individual palms were so striking that he laid down a second series from the same individual mother trees. In almost every case the general characteristics of seed from the same mother palm were identical in both batches. On the whole, large nuts showed a smaller percentage germination and less strong healthy plants than did those of more nearly average size. In both lots the germination percentage was around 60 per cent. after about five months. Perusal of his data shows that some populations produce no good plants whatsoever though the germination was 100 per cent.; others produced a large proportion with malformed shoots while others gave 100 per cent. germination all of which progeny were strong and evenly grown. The fact that some populations were comparatively uniform suggests either cross-pollination between very good type palms forming a compara-uniform G1 population which is not infrequently observed or else some self-pollination occurred in the generations preceding selfing. The significance of this will be explained in the section on plant breeding.

If, as it was shown in the Philippines,[40] round nuts give sturdier seedlings than oval-shaped nuts, despite the fact that there is little difference in copra content, this indicates that it would be preferable to use round nuts for seed purposes. The arguments advanced offer very good reasons why planting at stake should not be carried out under any circumstances, especially as there is a distinct possibility that a large proportion of the nuts set out will not germinate.

Selective Re-planting in the Field.

This is most necessary to assure that only sturdy, young plants of good type are perpetuated in the developed plantation. It is not possible to separate out all of the plants which are not likely to thrive from nursery selection. The wide variations in depth and type of rooting which develop after the plants are set out will give one very potent reason for this. The reader is referred to Sampson's text-book for a full description of variations in coco-nut root systems. Any injuries to the plant during transplanting or to the growing point by insects, rats or animals during the young stages provide a serious set-back to the plant for all time and injured plants should be replaced. It is an extremely wise plan to go over young plantings at regular intervals until the plants are well established. All plants which are not thriving and all misses should be replaced with strong and sturdy replants. The best time for replanting is while the surrounding palms in the plantation are still young so that the replants receive little root competition from older plants and are not deprived of necessary light and air while original humus from the forest soil is still present.

Necessarily, nursery management, nursery selection and replanting in the field deserve much fuller description than is given here, and would warrant treatment as a separate subject.

COCO-NUT BREEDING.

Objects of Coco-nut Breeding.

The main aims in coco-nut breeding depend upon which products are to be derived from the coco-nuts in the greatest quantities after the processes of manufacture. Since copra is the main product and the basis of all market transactions, the outstanding object should be to increase the yield of copra per unit area by all means available, and thus increase the yield of oil contained therein, as this ultimately determines the value of the product.

The use of improved planting material is one of the readiest and cheapest methods of attaining that end, as the yield of copra depends on the hereditary capacity of the palms to yield coco-nuts, although improved cultural methods, &c., would all have their effect. Reduction of cost of production is mostly readily attained by such increased yield per acre, or hectare, and must be given due consideration. For further information on the utilization of the coco-nut products reference may be made to a previous article in the *New Guinea Agricultural Gazette*.[24] There it is pointed out that oil content of the copra is most important, for it is the coco-nut oil which is mainly employed in the industries of margarine manufacture and soap-making.

So long as weight and appearance, and not the actual oil content, is the basis of selling the copra, the production of improved strains with nuts of higher oil content has been a secondary aim. This question of oil content cannot be disregarded as there is now a tendency instead of selling copra, to increase oil extraction, in the country of origin, such as has occurred in Ceylon, Netherlands East Indies and particularly the Philippines.

The definite question is whether it is possible to breed coco-nuts with an inherent capacity for high oil content and the answer appears to be in the affirmative. Work on this aspect of coco-nut breeding is being conducted in Malaya and Sharples, 1930,[54] points out that the oil content in coco-nuts, as ordinarily picked in estate practice, varies from 45-75 per cent.; but, since considerable differences exist in different pieces of meat from the same nut, and also in the meat from nuts of varying degrees of ripeness, the methods of sampling require standardization before selection for oil content can be usefully undertaken. The difference between oil content of ripe nuts and germinated nuts has been found to vary to as much as 7 per cent. It is possible, however, that this increased content is balanced by loss in yield.

Pieris, Ceylon, in 1934[46] states the problem very lucidly: "The main coco-nut products that are of commercial importance are copra, oil, desiccated coco-nut, and coir fibre. In the three former substances the important constituent is oil, and so improvement in their quality will be concerned mainly with increasing the percentage of oil in the kernel. It is not yet known whether this increase could be brought about by the use of particular manures on established plantations. Even if it could, such improvement will only be confined to that particular generation which has been treated and will not be handed down to the offspring. There is little doubt, however, that, from a genetical point of view, it is possible to breed coco-nuts for increased production of oil. This can be done in one or two ways—

1. By keeping the quantity of the kernel constant and breeding for high oil content of the kernels.
2. By keeping the oil content of the kernels constant and breeding for high weight of kernels".

The combination of the two methods is also a possibility. It will be seen, however, that of the two aims that concerned with the actual increase of weight of kernel is now the main objective due to present marketing practice. It is apparent that the important consideration is to increase the production, or high yielding capacity, of the individual coco-nut palms. It is certain, however, that there are other important objectives which must be considered, such as—

1. Yield of a high quality product with a high oil content, as previously mentioned, should be combined with the gradual elimination of poor yielding palms.
2. Inherent vigour and longevity.
3. Uniformity as far as possible, which is linked with 1 and 4.
4. Regular bearing of heavy crops and elimination of alternate bearing.
5. Development of early maturing, heavy-yielding strains. The comparatively long time which it takes coco-nuts to come into bearing greatly influences the cost of establishment in plantations. It is well known that some palms come into bearing much earlier than others, in any plantation.
6. Elimination of genetical weaknesses such as liability to chlorosis, frond choke and so on. This is also related to No. 2.
7. The production of improved strains suited to a wide range of environment. Improved material suited to only a limited range of climate and soils would exert little influence on improving the present position. Experiences with other crops indicate that there are great possibilities of producing improved strains, which would do well under a wide range of conditions.
8. Ease of harvesting where picking is practised. Short, high-yielding palms would be preferable providing all other factors were equal.
9. Development of disease and pest resistant strains. This should be one of the most important aims in coco-nut breeding. Casual observations, and actual experience with other crops, indicate that there would be definite chances of isolating populations with resistance to such diseases as "Thread Blight", *Corticium penicillatum*; and "Leaf Blight", *Pestalozzia palmarum*. With the method of close breeding described later, this should be a most definite aim of improvement.

COCO-NUT BREEDING TECHNIQUE.

(Mainly Semi-Technical.)

Coco-nuts belong to the great division of Monocotyledonous plants as opposed to the other main group of Dicotyledonous plants such as rubber or cacao. The plants belonging to the former group usually have only a single growing point and have not the power of annual increase in growth, such as occurs by cambial activity in plants of the latter group.

It appears, from analogy, that the behaviour of coco-nuts, on self or cross pollination, would be somewhat comparable with what is experienced in maize breeding; the latter being an annual Monocotyledonous plant. The reasons underlying this statement are linked with the fact that the problems of maize breeding have received much more attention than is the case with coco-nut breeding. This can be largely attributed to the greatly increased chances of getting quick results with maize breeding and of raising improved strains of the crop within a comparatively few years. The relative economic importance of maize as a food-crop, in all parts of the world, also assures that this plant receives much attention from plant breeders and geneticists. Some methods of breeding which are employed in breeding maize appear, undoubtedly, worthy of application to coco-nut improvement.

The long term of years which is involved in anticipating results from coco-nut breeding has provided one of the greatest deterrents in the improvement of this crop by artificial self and cross pollination methods, although various kinds of mass selection have been employed in some countries. It is of great interest, however, to note that coco-nut research schemes have been evolved in various parts of the Colonial Empire, such as Ceylon and Malaya and in such outside countries as the Dutch East Indies, particularly in the Celebes. It is the policy of this Department to introduce any improved planting material from such sources wherever possible. In this connexion, as mentioned before, some improved strains have already been introduced from Menado, Celebes and from the Landbouw Instituut at Buitenzorg, Java, through the courtesy of the Dutch authorities.

Hunter and Leake[28] state "that the improvement of coco-nuts and building up of super-types is a problem, which owing to the absence of the genetical purity of the available material, together with the time interval between generations will appal the stoutest-hearted breeders. The scope for improvement of the crop is considerable, but owing to the age to which the plant grows the methods for securing that improvement must necessarily be tedious".

Jack, 1922,[31] remarks that "the production of pure strains of coco-nuts which is the only certain method of producing uniform and high-yielding strains, lies beyond the power of the planter, because it necessitates initial work stretching over at least three generations of trees during which period much attention has to be paid to detail and great patience must be exercised."

This rather stretches the position in regard to uniformity as modern plant-breeders dealing with the improvement of crops liable to cross-pollination are not slaves to uniformity so long as a measurable increase in yield and uniformity is obtained. "Strain building" to develop a high proportion of hereditarily high yielding types in the population is a more progressive aim for plant breeders with such crops and this must be carried on continuously. Experiences with such crops as maize indicate that it would not be possible to get genotypical uniformity such as is possible in self-fertilized crops. Planters can greatly assist the building up of superior strains when they use intelligent methods of seed selection on their plantations. Then by utilizing plant breeding methods it is possible to capitalize on such ground work done on the plantation to a larger extent.

It is a most apparent fact that the very height of well-developed mature, tall coco-nut palms is one of the greatest reasons why artificial pollination methods have not been developed on a large scale. This fact also explains largely why

very little artificial pollination work has been done even in an investigational way on tall palms while there is far more data available for dwarf palms. The usual height of a well-grown palm ranges from 40 feet to 100 feet from the ground. Palms have been measured here which are over 110 feet. Some have been recorded from Malaya which are nearly 200 feet, while Burkill[65] measured palms there which reached 120 feet.

It is no easy matter to carry on pollination investigations at even half the height mentioned as some kind of staging is essential for each palm if the investigator intends to supervise the work closely. Failing this reliance would have to be placed in a native or Malay to do the work under direction, which would be only partially satisfactory. It is clearly a very big job to cage or bag individual spathes on large numbers of palms under such conditions, and this provides a distinct limitation to the scope of controlled pollination. This consideration alone increases the value of methods of close-breeding in such work.

Self and Cross Pollination in Relation to Vigour and Fertility.

The effects of self and cross pollination in relation to vigour and fertility of coco-nut palms are not clearly understood due to the small amount of work on this aspect of coco-nut breeding. Tall coco-nuts are said to be liable to natural cross-pollination. It can be assumed that individual palms are also liable to natural self-pollination, even if it is to a lesser extent, and it is more prevalent in particular varieties under particular conditions. Owing to floral structure, maize is known to be extremely liable to cross-pollination, but even in that crop, natural self-pollination is known to occur. The results of the investigations already carried out on coco-nuts are conflicting, apparently. It has been shown, for example, that cross-pollination is more prevalent in some palms at some elevations than at others. This is not such an important consideration to the plant-breeder as is the physiological effect of self as opposed to cross fertilization, in either decreasing vigour in the first instance (in-breeding) or of increasing vigour in the second instance (out-breeding) causing hybrid vigour (heterosis).

Investigators generally concede that cross-pollination, by different individual palms is most effective in favouring maximum nut setting. To what extent cross-pollination would increase the nut setting, over artificial self-pollination, has not been sufficiently proved, and much more work is necessary in that direction.

The earliest work in the direction of in-breeding is of too recent a date to give even an indication of the effect of such in-breeding on the loss of vigour. As stated previously the work on other crops of the Monocotyledonous group, which are liable to self-pollination, such as maize, would, by analogy, suggest the probability of the loss of vigour where tall coco-nut palms are subjected to in-breeding.

Such very fundamental knowledge concerning the extent to which this loss of vigour occurs is essential before a successful scheme of plant-breeding can be evolved and it is essential that the work be carried out.

The examination of seedling progenies from even once-selfed flowers should give a very good measure as to whether some palms are more liable to cross-pollination than others. Such work would also give some indication as to whether some progenies breed truer than others and as to the amount of self-pollination

in the generation preceding selfing. Although Smith[56] did not draw any such conclusions, from his work in Malaya, the presence of comparatively uniform progenies, as well as varying populations in the coco-nut seedlings from open pollinated palms, which he had under observation, suggests very interesting possibilities. It appears likely that either he was dealing with first generation (G1) crosses between good palms leading to comparative uniformity or else self-pollination does occur in some generations. This is comparable with what has been found in lucerne and coffee breeding for example.

Some palms which have been isolated at some considerable distance from other coco-nuts have been noticed to bear fairly well here; this has also been recorded elsewhere[29B]. This fact suggests the possibility that some coco-nut palms would be more liable to self-pollination than others. This contention is borne out by the behaviour of almost all cross-pollinated plants, where "heterosis" on hybrid vigour is a well-known phenomenon. Indirect support of this statement seems to be borne out by the fact that the dwarf coco-nut in Malaya is believed to have originally originated as a sport or mutant from the tall coco-nut. The Malayan dwarf is known to vary somewhat though not nearly so much as the latter. Jack and Sands[32] are inclined to the opinion that the dwarf group shows greater definiteness, because of the fact that it is commonly self-fertilized. Maréchal[41] on the other hand has concluded that cross-pollination is more the rule with the dwarf types normally growing in Fiji. It was shown conclusively in Malaya, that the dwarf forms will cross up with the tall forms, so that semi-talls or intermediate forms may be found. This could be expected to give rise to a wide range of behaviour as to the ability to self-fertilize. It seems that owing to cross-fertilization it will not be possible to originate strains or varieties of coco-nuts which have the faculty for breeding true and thus have the definiteness. which is applied to varieties derived from plants which are normally self-fertilized. The question of the effect of cross-fertilization as opposed to selfing on the size of the resultant nuts should be an extremely valuable study.

Methods of Breeding.

In an article on lucerne breeding technique by the present author[14] the methods of breeding that crop plant are described in detail. They are not all applicable to coco-nut breeding, but a system of close-breeding was described, which, in the author's opinion, would have considerable use in the improvement of coco-nuts.

The following methods of plant breeding may be outlined as available for the improvement of crops. The question is which methods have utility for the particular work of coco-nut breeding:—

1. Introduction of strains, varieties, or nationalities.
2. Artificial self-pollination, selection in self-fertilized lines and their recombination (self-pollination methods).
3. Hybridization—Naturally or artificially.
4. Mass selection and strain building.
5. Plant to row methods.
6. Close and line breeding.

It is not intended to describe each of the above methods, but rather to indicate the application of such methods to coco-nuts improvement.

1. Introduction of Strains, Varieties or Nationalities.

This obvious method of increasing the range of suitable material available for selection and breeding has been already dealt with in the first section of this article. There is a danger of introducing new diseases from outside countries, attendant on this method, which needs to be closely watched.

2. Self-pollination and Recombination Methods.

The importance of self-fertility studies in coco-nut breeding has been mentioned in the section dealing with the relationship of self-pollination to vigour and fertility. Methods of in-breeding and recombination to increase vigour and yield such as is done with annual crops does not appear to offer much scope in practical coco-nut breeding. The long generations involved in this work means that this work would have little application except as a means of determining loss in vigour. It could also be done to determine which palms would be most suitable for recombination and crossing by other methods.

Artificial Self-pollination.

Pieris[8] concludes from his experiments with fresh and stored pollen that the possibility of artificial selfing of coco-nuts, in Trinidad, was definitely established. The experiment was on a very small scale as he obtained only three nuts from fourteen flowers pollinated, where he used pollen from the same inflorescence as the female flowers, collected before the male flowers shed and stored the pollen for seven days.

Jack and Sands[31] working with "dwarf palms" on which three unopened inflorescences were bagged in muslin bags, stated that self-pollination was effected naturally and fruits were formed.

In three other inflorescences which were emasculated (male elements removed) immediately on opening, no pollination took place, and no fruits were formed, though the female flowers behaved normally and although male flowers on adjacent trees were in full bloom. The question of whether these flowers were self-pollinated requires more proof; firstly, because the numbers were small; secondly, because any injury due to emasculation was not taken into account; and, thirdly, it is not certain that wind-borne pollen is excluded by muslin.

To control the parentage of seed nuts the flowers of the palms must be protected against foreign pollen. Emasculation of the male flowers on the individual spathes is also essential, and any injuries caused thereby should be checked by control tests.

Bagging must also be carried out with material which precludes any possibility of the entrance of wind-borne pollen or of pollen carried by crawling insects. This is especially the case where artificial self-pollination is being carried out. The meshes of most muslins are too far apart to exclude fine wind-borne pollen as has been found in special experiments designed to test this in such temperate crops as lucerne. Bagging with muslin bags, undoubtedly, provides some impediments to the free entrance of pollen, but does not necessarily exclude all pollen, especially where heavy winds occur. Against this, there is the fact that bagging with air-tight bags, or with bags which exclude light, usually produces conditions which are unfavorable for fertilization.

Van der Wold[62] has shown that the ripening of female flowers is hastened by covering them with black paper, so as to reduce light and warmth. If the female flowers can be covered so as to become receptive at the same time as the male flowers on the same spathe, then the problems of artificial self-pollination are greatly lessened. It is most likely that the differential environments in close proximity to the flowers may have their effects in rendering flowers liable to self-pollination in some places and not in others. Temperature and humidity can be just as easily increased by using other coverings, such as plate mica or glass, hence a big field for research is opened out.

Furtado[22] obtained results by emasculation experiments on dwarf varieties which differed from those obtained by Jack and Sands (*loc. cit.*). He was able to obtain nuts even though the nearest tree from which pollen could be brought was about 50 yards away from the palm he was working on. This happened despite the fact that the inflorescences looked sickly, and nectar secretion was reduced because of the injury resulting from emasculation.

There is still very much room for investigations in artificial self and cross pollination studies, even before a proper technique is evolved or perfected. Such work is said to be now proceeding in Malaya. Owing to the very height of mature tall coco-nuts and to the comparatively few female flowers found on each palm, the carrying out of extensive pollination studies is no easy matter on such palms. Studies of this nature are not properly significant, unless carried out on a comparatively large scale over long periods of time.

Artificial Cross-pollination.

Maréchal[41] crossing dwarf palms in Fiji obtained a set averaging about 30 per cent. of the flowers artificially cross-pollinated. This compares with the percentages of natural set recorded by other investigators elsewhere.

Pieris,[8] when artificially crossing ordinary Trinidad coco-nut palms, obtained a set of six nuts from 38 flowers (approximately 16 per cent.) when fresh pollen was used, and two nuts from eleven flowers from fresh pollen stored seven days in a gelatine capsule.

It is apparent that the amount of artificial cross-pollination, so far attempted, is very limited and that it would be very unsafe to draw many definite conclusions from such work. Cheeseman[8] comments on the bagging of emasculated inflorescences by Pieris as follows:—

> In waxed paper bags all flowers shed in a few days, but the dark humid conditions inside the bags may have been as much responsible as the complete exclusion of the pollen.

In fine meshed muslin bags ten flowers set nuts out of 156 enclosed, equal to 6 per cent.—from general observations it was concluded that these were probably due to wind-borne pollen and not to ants. In coarse meshed bags out of 70 flowers enclosed, 22 set nuts or 31 per cent. When emasculated flowers were left freely exposed, 42 flowers out of 108 set nuts or 39 per cent.

Hybridization—Cross-breeding.

The value of artificial cross-breeding as a practical method of breeding coco-nuts has not been elucidated, though, as mentioned before, it has been tried in Fiji. It is an accepted method of conducting inheritance and pollination studies. The isolation of desirable types for natural cross-pollination and the establishment

of isolated seed gardens, which comprise only progenies of selected palms, sown in separate rows so as to facilitate both observation and natural crossing, must be considered as to feasibility.

The provision of isolated seed gardens has been used by rubber companies with success in increasing yield.

Another method which suggests itself is that artificial self and cross pollination be carried out with certain selected mother trees to test their behaviour. Then seed nuts from the best proved palms could be isolated together for natural crossing by systematic interplanting as for example two rows derived from each palm sown diagonally in apposition. The practical difficulties associated with established coco-nut seed gardens would be the location of suitable areas at sufficient distances from other coco-nuts, and, secondly, the difficulty in raising sufficient seed for distribution on a commercial scale; while the time and cost involved in getting results must be considered. It is not known, for certain, whether improved strains raised under the environmental conditions obtaining in one district would suit other areas. The probability is very great that strains can be evolved which would do so.

Recently to hand is an account of some carefully planned coco-nut cross-breeding work conducted by Dr. Patel(68) at the Agricultural Research Station, Kasaragod, Madras Presidency, India. "It was found that on an average of twelve years, 13 per cent. of the trees yielded 21 per cent. of the total crop and 7 per cent. of the trees produced only 2 per cent. The characteristics of these 13 per cent. eco-types of the palms are: (1) presence of relatively a larger number of leaves in the crown, which is not so much due to the higher production of leaves as the greater longevity of the leaf, (2) reduction in response to cultural, manurial and seasonal conditions. Apart from the variations in the yield of nuts, these eco-types vary in the production of female flowers, the setting, the size of the nut and the thickness of the meat. In order to determine whether this variation is inherited and to what extent it is possible to combine these characters, crosses have been made between the eco-types exhibiting these characters. Suitable selfed and naturally pollinated material forms the control. About 30 per cent. of the population is not regular in the production of nuts. Crosses have also been made between regular and irregular bearers. It is well known that the dwarf type of the palm commences to yield earlier than the ordinary tall type. The dwarf type and the tall eco-types have been crossed. It was found that a larger proportion of crossed nuts germinated earlier than the selfed and naturally pollinated nuts, and among the crosses those with the dwarf male as one of the parents germinated most rapidly. On the whole it is found that variability with regard to the characters like the period for emergence of successive leaves, and the height and the girth of the seedling, are more in the F1s than in the selfed first generation. Of the progeny of the twenty tall type of parents, tree No. 1/121 and 11/107 are superior in respect of the above-mentioned three characters and also in respect of early separation of leaflets. It appears that the progenies of parents producing a very large number of female flowers are better than the progenies of trees yielding exceptionally well. The development of the F1s of dwarf x tall crosses is outstanding".

[Eco-types represent strains of similar appearance and behaviour, in one generation, but whose progeny do not necessarily behave in the same way in subsequent generations, i.e., phenotypically similar types.—*Author.*]

It is proposed to cross the Markham Valley type of palm with the Malayan dwarf coco-nut at Keravat, also to cross the tall palm in a similar manner and at the same time carry out the reciprocal crosses, using only selected palms in this work. A big handicap, as far as carrying out such technique in New Guinea, is that the local native has not the same intelligence and adaptability as, say, Javanese, Malays or Indians. This means that the investigator here has to work in a small way, although larger scale operations would be decidedly preferable.

Colour Variations in Cross-breeding.

Govindu Kidavu(67) describes a very interesting colour variation in a coco-nut palm growing on Kalpeni Island, in the Laccadives. In this instance three bunches contained green nuts, one bunch with yellow nuts and another, a fifth bunch, with both yellow and green nuts. [He does not describe it as such, but this is a most interesting chimæra or somatic colour mutation, commonly known as a sport.—*Author.*]

The obvious inference is that there is only a (one) factor difference between the green and yellow nuts. Further the chances are that yellow is recessive to green and would breed relatively true to type for that particular character. It is also a significant fact that the colour of the nut is generally correlated with that of the leaf and flower stalk. Counts seem to indicate that red colouration is also recessive and is governed by two or more factors, but further information is required on that point. This question of inheritance of colour differences should be of great import to coco-nut breeders.

Natural Cross-breeding: Assisted by Selection of Male Palms.

As the aim is to evolve practical methods and not academic methods of coco-nut improvement it is as well to mention a method of isolation of mother palms combined with selection of male palms which has been advocated.

The first procedure is to select an area of good yielding palms on an isolated island of rather small size, or else an area of palms completely separated from other palms by wide stretches of bush country. Then the worst mother palms are meant to be cut out or prevented from flowering. Selected male spadices from selected marked palms are then brought in from any outside areas where good parent palms are known to exist. These spadices are tied on to the selected palms on the island which are thought suitable for crossing. It should prove practicable to emasculate the spathes of selected palms. This is not a controlled method as outside crossing could not be altogether prevented, nevertheless, it is a definite practical attempt to control the parentage. An improvement on this method would be to use means of keeping the male spathes alive and actively shedding pollen for some time. That this may be done by using an acid solution as is done with sugar-cane crossing is quite possible. This was demonstrated to the author by Lennox(37) who used a solution of 5 per cent. sulphurous acid H_2SO_3 + 31 per cent. aqueous solution of H_3PO_4, ortho-phosphoric acid in his crossing work with sugar-cane. This solution keeps the sugar-cane fuzz alive for a long time when the base of the stalk is immersed in rubber containers containing this solution. It remains to be proved whether some such means of keeping the coco-nut spathes alive for a long time would be successful.

Mass Selection.

It is seen from the description of the methods of coco-nut seed selection employed in New Guinea that rough principles of mass selection are often employed here, though, in the vast majority of cases, not in an organized manner. As a short-term outlook, the greatest advances from the practical point of view may be expected from this mode of approach to the problem; hence practical seed selection as outlined should be encouraged in every way. Controlled mass selection combined with individual plant selection should also be a necessary prelude to any programme of coco-nut breeding. It has been stated that mass selection, properly employed, offers a ready means of capitalizing on the work which nature has already accomplished, through natural selection, over long periods of time. The term indicates that coco-nuts from selected palms, or selected areas of palms, are used for bulk plantings. The procedure could allow for the cutting out of inferior and diseased palms and only allowing the best palms to cross in an area designed for seed production, and also prevention of inter-crossing by other means such as the removal of spathes on such inferior palms.

Plant to Row Methods.

This appears to be comparable with the methods employed at Klang, Coco-nut Experimental Station, Malaya, and at Buitenzorg, Java. This would be a very useful method to employ either in the preliminary stages or as an adjunct to the close breeding methods described later, and would also be very useful for establishing isolated seed gardens. The seed nuts or progeny derived from palms which appear to be superior on appearance, or as indicated by the various criteria used for selecting good palms, or preferably by previous yield records, are sown out in rows for comparison and further recording of yields. It is possible to cut out any rows which are inferior in type or in yield capacity and thus allow only the best types to cross. A necessary preliminary to either plant to row methods, or to the provision of isolated gardens or to commencing close breeding, is proper nursery selection. Only progenies which give a high percentage germination and produce strong healthy seedlings of even growth should be planted out regardless of the individual yield records of the mother tree. Hence, even in the nurseries, it would be a sound plan to arrange the coco-nuts derived from each individual palm (plant progenies) in rows, side by side, under optimum conditions. Then the hereditary behaviour (plant to row) of individual palms can be judged to some extent even in the very early stages. The production of even, sturdy plants means that both parents were strong and that few variable, inhibitory or undesirable characters are present.

It is common knowledge that plant to row methods has led to great yield increases in other crops, liable to cross-pollination, and is also indicated as a means of coco-nut improvement, though it is of necessity slow, from the practical point of view, unless extensive areas are planted out. It should be recognized that improvement of yield might accrue, but the yield of improved nuts might not be on a sufficient scale to influence large commercial plantings.

When using controlled plant to row methods it would be necessary to obtain results which would yield sufficient seed coco-nuts to be of practical value to the planting community. It is an important consideration that the difficulties of

utilizing improved coco-nut material are great, because it would be necessary to have sufficient seed nuts developed finally to be available for public use, so as to warrant any expenditure and work carried out.

Close and Line Breeding.

The most important desiderata centre around the question as to whether breeding of coco-nuts is practicable and whether results can be expected to eventuate within a reasonable period of time at comparatively reasonable expenditure.

In rubber breeding vegetative propagation furnishes a ready means of capitalizing on any progress made in breeding and provides methods of increasing any high yielding tree to any sized population required. This development of large population from one individual plant by vegetative propagation is called "clonal propagation" and the population so developed is termed a "clone". Rubber clones have been developed and increased so that many thousands of acres have been planted with individual buddings originally derived from one tree.

There is no such short cut to coco-nut breeding, hence it is necessary that some scheme be evolved, which as far as possible can be fitted in with the commercial running of a plantation while still furnishing some measurable improvement in yield and type.

It appears to the author that the only probable means of attaining the desired end is by a system of "close-breeding". Investigators who are interested in a discussion of this breeding technique are referred to an article published in *Herbage Reviews*, March to June, 1936.[14] The reasoning applied by Macauley[39] for close-breeding with maize suggests the basis which can be used for close-breeding of coco-nuts, although important modifications will be found necessary. The limited programme which has already been commenced at Keravat Denonstration Plantation is now outlined. It is also pointed out that the programme of close-breeding is combined with the scheme for the introduction of superior selected coco-nuts, both from within and outside the Territory. Seed coco-nuts derived from open pollinated flowers of selected individual palms are collected and numbered. The seed nuts from each individual palm are kept in separate plots in the nursery. The seedlings are selected in the nursery before planting out is done as is described under line breeding. At Keravat these are later planted into distinct and separate plots in the field. It has been the practice here to plant out the seed nut population derived from each individual palm into small square blocks in the field. Owing to space consideration only one dozen seed nuts from each mother palm could be used in each individual plot.

It is seen that the behaviour of the mother trees can be determined, and that the pollen or male parent is the unknown factor, owing to the ease with which cross-pollination apparently occurs with coco-nuts. It seems very difficult to obviate this, except by controlled cross-pollination in the first place, or by the more crude method of hanging spathes from selected palms to act as male or pollen parents for the selected mother palms.

The elimination of inferior types in the first series can be done by observation and perhaps by weighing the husked coco-nuts when the palms come into bearing. Any obviously bad populations such as those with a tendency to chlorosis or any growth malformations will be eliminated before the palms come into bearing at all.

The term "close breeding" is derived from the fact that, as far as possible, the pollen produced by the individual palms in one population is meant to fertilize flowers of other palms belonging to same population, all of which were derived from nuts harvested from the same individual mother tree.

In practice it will be difficult to prevent the intermixing of the pollen of the various populations, but some precautions are indicated to eliminate this possibility, as far as possible.

When selecting nuts for further plantings all that can be advocated, is to select nuts from the centre of the best plots. It should prove possible to remove spathes from the palms on the borders of each individual plot, and thus prevent their fruiting. This would be more practicable with short or young palms. It must be conceded that even by observational methods, many inferior populations will be recognized. These can be cut out and eliminated from any possibility of crossing so that any outside crossing which does occur should be with individuals of superior populations. At such time as it is possible to recognize any superior populations, the next step is to plant seed nuts from these together, as separate plots, in a new area. If possible this second stage should be arranged for yield testing as well as to give maximum facilities for close pollination. Close-bred plants are sufficiently variable (heterozygous) so as not to lose vigour after continued selection in the close-breeding plots.

It is considered that a continuous system of close-breeding would permit of the continuous elimination of inferior strains after each generation until finally only the best strains, as determined by performance on yield, or under observation, are perpetuated. Such a process of elimination really amounts to "strain-building" and does not preclude the building up of other improved seed plots from the best strains, at any time, without interfering with the programme of improvement and without loss of vigour in the resultant progeny.

It seems possible that it will be necessary to wait for some years to obtain an improved strain of seed coco-nuts for multiplication and distribution, but in any case the method described offers the quickest means available. Another advantage is that this improvement should be increased with each generation of further selection.

Practicability of Coco-nut Breeding.

The objectives and practicability of coco-nut breeding are stressed right throughout this article, but there are other difficulties which present themselves. It must be decided whether the introduction of comprehensive programmes of coco-nut breeding such as described is warranted. The possibiliites of controlled coco-nut breeding are surveyed in this article, but it is seen that the problems involved are not simple, and that there is no set road to success with such work. One certainty is that it would be advisable to carry out coco-nut breeding by all practical methods available, which is no limited task.

Such controlled plant breeding cannot be carried out by private individuals, and is a matter for institutions which must devote most of their time to such work. The question as to whether the economics of the present situation merit such work on a large scale devolves upon the fact that a large proportion of the available areas have been and are becoming planted up with ordinary type coco-nuts. Against this argument it must be pointed out that it is not known what proportion of the bearing areas in the South Seas are economic producers or in

other words to what degree the good producing areas are carrying the low-yielding areas, on the individual plantations. It is certain that an economic survey would show that a great proportion of the bearing areas in this Territory become uneconomic producers when the price of copra falls below a certain level. This applies more particularly to the low copra producing plantations situated on infertile soils. If improved planting material were available this marginal yield per unit area would be increased in the same ratio as any yield increase obtained by using improved seed nuts.

The heaviest bearing plantations and thus the most economic producers stand the most chance of competing with other countries and other competing oils when the margin of profit is reduced owing to a fall in prices. By using improved seed nuts areas which are at present uneconomic might be brought into cultivation. There is no doubt, whatsoever, that the use of improved seed material, if available, would greatly lessen cost of production.

Facilities Necessary.

It is obvious that the provision of facilities is really the determining factor as to whether such work should be commenced or not. A great consideration is whether it would pay an individual Government in a partially developed country to inaugurate such work where questions of fairly heavy finances are involved.

It would, undoubtedly, require that a whole plantation be devoted to such work. It seems, however, that if such breeding and selection work were carried out on a large scale, the plantation used could be made to pay for most of the expenditure involved, once it is brought into bearing. The precedent for this is where the areas devoted to coffee and rubber breeding have been made to pay where such experiment stations were established elsewhere.

It appears that the ideal plantation for such work would have about 100 hectares already in bearing to help carry the expenditure. This would serve as a source for solution, and would provide areas for manuring and other experimentation. This bearing area would need to be associated with at least as large an area of virgin country to carry on breeding programmes, such as described. There is little doubt that it would be possible to plant up a whole plantation of, say, 100 acres with coco-nuts arranged for close-breeding in the manner described. It would be preferable to plant 25 or 50 nuts from each palm in the individual plots. Then it would not be unnecessary to remove any spathes to insure that there was sufficient close-pollination within the centre of the plots, while cross-pollination would take place with the adjacent plots on the borders. Where these adjacent plots appeared to be both superior types, crossed nuts, derived from the edges of the plots, may provide very useful material. Where larger plots were used it would be possible to supply much more material from selected plots. It would be necessary to select the original mother trees by using the various criteria and known correlations between desirable characteristics, earlier described. In this manner, it should be possible to select only high producing, good type palms for inclusion in such a programme.

Such a large area could be run commercially and would be used for experiments and still act as a main centre for seed distribution. If planters were interested in first-class seed nuts, a small extra charge could be made for improved material. The initial cost of establishing such a coco-nut research centre is, as with most new ventures of this nature, the important consideration.

Should the provision of such a plantation be beyond the resources of any one individual Government, it is possible that a scheme could be made to apply to the whole Southern Pacific, if some well-organized central institution were available to carry out such work, but so many Governments are involved as to render such an establishment unlikely. The time factor is a most important consideration, and it is this more than anything else which has held up coco-nut breeding for so long. It is only a Government or an institution with a long-term viewpoint which could satisfactorily carry on such work.

There is no doubt that the development of improved seed nuts would have a wide application, as the results would apply to most coco-nut-producing countries, but particularly in those Pacific Islands where European plantations form the bulk of the planted area. There is not only the desideration as to whether coco-nut breeding is a feasible aim, but there is the question as to whether sufficient seed nuts could be increased from any improved strains to affect a great number of plantations. It is this consideration which determines that any controlled system of coco-nut breeding would necessarily have to be carried out on a large scale.

If it were considered by central authorities and plantation interests that the work of developing improved seed nuts would be of great value, the institution of such a programme should not be delayed.

It is as well to realize the difficulties involved, but an important function of this article is to show that the feasibility of controlled coco-nut breeding has been given much consideration by this Department. It is granted that the question of the establishment of such a scheme of coco-nut research could not be decided by any particular individual, or even by this Department, without the full co-operation of all interests affected.

Besides the major objective of developing improved strains of coco-nuts, a coco-nut-breeding station could carry on fundamental studies with all the problems mentioned in other sections of this article.

A study of self and cross pollination as related to fertilization and nut-setting could be carried out in connexion with the breeding programme, as could investigations on other factors affecting nut-setting.

Experiments on manuring, cover cropping and cultural methods could be carried out at the same time. Such work would indicate the quickest methods of increasing yields for any money expended. The longer term results from controlled plant breeding should, however, be more permanent and progressive.

SUMMARY.

This article deals with two main problems, and hence is divided into two main sections: A.—Coco-nut Seed Selection; B.—Coco-nut Plant Breeding.

A.—Coco-nut Seed Selection.

In problems of seed selection the effect of environment on the growth characteristics of the coco-nut cannot be underestimated. Unfavorable environment may mask favorable hereditary characteristics of the individual palms and render selection difficult.

The hereditary characteristics of a palm which determine its inherent capacity for yield are constant, but the factors associated with the expression of yield—such as climatic, soil, and cultural environment—are constantly changing, and these are briefly outlined.

Individual palms in any plantation show a wide range in growth characteristics and in fruiting ability, so that in any unselected area a very large proportion of the palms present are shown to be uneconomic producers, thus coco-nut seed selection is strongly advocated.

The methods of seed selection employed in New Guinea plantations are outlined. These are usually crude, where not entirely neglected, though a few experienced planters do practice proper seed selection. Excuses advanced for such neglect mainly centre around the time and cost involved, though it cannot be denied that seed selection is a sound capital investment.

Improvements on the existing methods are described and recommended. Heavy-bearing palms of good type should be selected according to various criteria which are elucidated. The selected palms should be permanently marked and observed, individually, for some time before finally selecting them as a source of seed supply.

Certain external characteristics, such as type of crown, number of spathes and female flowers present, have been correlated with yield tendencies. In other countries a very high correlation between weight of husked nut and copra yield has been indicated; thus by simply weighing the husked nuts a very close measurement of the yield of copra from individual palms can be made without the trouble of drying the kernel.

The tangible results which can be expected from seed selection are indicated as being well worth any cost or trouble involved. Yield increases of the order of 20 per cent. would easily be anticipated, if rigid selection of high-yielding palms for producing seed nuts were carried out as, on the average, high-yielding palms produce high-yielding progeny, and vice versa for low-yielders. If production can be increased by 10 per cent. the cost of selection would be amply repaid.

The extent to which coco-nut seed introduction into New Guinea has proceeded since historical times is not generally realized. The introduction of seed coco-nuts from outside countries such as Malaya, the Philippines, Java and Samoa, and seed interchange between various parts of New Guinea, has been carried on extensively both during and since German times.

The present Department of Agriculture has also carried on a great deal of coco-nut seed introduction, and representative collections are being grown at Keravat Demonstration Plantation near Rabaul in connexion with a breeding programme.

The presence of "regional strains" (not varieties which breed true) in this country and elsewhere are indicated. It is apparently this fact which has led to the interchange of seed nuts from different districts here. The Markham River, Witu and probably the western islands types of coco-nuts appear to be varying regional strains which, however, possess some distinguishing characteristics. The influence of selection of seed coco-nuts by natives, together with natural selection, has had a decided influence on the types of nuts propagated in different districts.

A short discussion on coco-nut varieties is presented and several genetical abnormalities, which should be avoided when selecting seed nuts, are listed. The utility of the dwarf varieties to New Guinea conditions is not yet apparent, but they have been the subject of many inquiries, and hence are described in some detail. Some types were introduced years ago by German planters.

The floral structure (morphology) of the coco-nut spathes and flowers, also the development of the inflorescence, male flowers, female flowers and nuts are dealt with, and many practical applications of such work are given.

The natural nut-setting or the percentage of flowers forming matured fruits (usually in the vicinity of 30 per cent.) is influenced by the original profuseness of female flowers present, as well as by the general condition of the palms, together with all of the factors governing growth, fertilization, and so on; closely related to this are the problems of nut-fall. The falling of unfertilized flowers (embryo abortion) is often confused with nut-fall.

The problems of pollination and fertilization of coco-nuts are presented, while the agencies of pollination, such as insects, wind and birds, are discussed with particular reference to New Guinea. Knowledge of such problems is a necessary preliminary to any controlled methods of coco-nut breeding.

A brief discussion on seedling selection in the nursery and selective re-planting in the field is given, although these may be treated as separate subjects. Insufficient attention is given here to these most important precautions for successful coco-nut planting. The seedlings being derived from originally cross-fertilized flowers show extreme variations, and only the sturdiest plants should be selected for planting out. Neglect any palms showing an hereditary tendency to low germinability of seed nuts.

B.—Coco-nut Breeding.

It is only recently that scientific plant-breeders have taken an interest in the improvement of coco-nuts by systematic plant-breeding.

The long term of years which is involved before any results could be obtained from coco-nut breeding, the height of the palms, and the long intervals between generations, have so far provided the greatest deterrents to the initiation of plant-breeding with this crop.

The possibilities of controlled coco-nut breeding as far as New Guinea is concerned are surveyed in this article, and it is shown that the problems involved are not simple; nevertheless, they are not insurmountable.

So far few results have been obtained anywhere from methods of controlled breeding of coco-nuts, and hence the literature and information available on the technique likely to be employed in such work are very meagre.

Controlled plant-breeding cannot be carried on by private individuals, as it is a matter for institutions, which must devote a great deal of their time to such work. The objects of coco-nut breeding, such as breeding for yield of copra, oil production, elimination of disease, actual increase of copra production, constitute the main aims in such work.

A most important consideration is not whether controlled breeding of coco-nuts is practicable, but whether results can be expected to eventuate within a reasonable period of time at comparatively little expenditure.

The difficulties of utilizing improved coco-nut material are stressed, as sufficient improved seed nuts would need to be produced to affect a large planting area, in order to warrant the trouble and expenditure involved.

The question of the provision of facilities, and a suitable plantation for such work, is discussed, and this is really a determining factor governing the initiation of such work in this country.

The effect of self and cross pollination on the vigour of the resultant palms is outlined. Self-pollination leads to in-breeding, which leads to reduction of vigour in crops liable to cross-pollination, such as coco-nuts.

The possible methods of coco-nut breeding are described and it is explained that controlled mass selection, combined with individual plant selection, should be a necessary prelude to any programme of coco-nut improvement.

Six methods of crop improvement are outlined, and these include the possibility of artificial pollination methods being employed.

It is believed that "close-breeding" methods, and the provision of various kinds of seed isolation gardens, offer the readiest means available for coco-nut seed improvement.

Such methods are being utilized on a limited scale at Keravat Demonstration Plantation, near Rabaul.

Acknowledgment.

Acknowledgment is made to C. H. Meen, Chinese Clerk, for most of the photographic work.

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CORRESPONDENCE.

[*The Department does not necessarily concur with the opinions exressed, but correspondence and articles are always welcomed.*]

Erimahafen Plantation,
Madang, New Guinea,
1st November, 1937.

The Director,
Department of Agriculture,
Rabaul.

Dear Sir,

It was noticed in the early issues of the *New Guinea Agricultural Gazette* that the planters were invited to contribute articles to this journal, but I have not as yet read any articles originating outside your Department.

As I consider it the duty of the planting community in general to assist you in establishing this journal—a very necessary publication for the improvement of the Territory in an agricultural sense—I am attaching herewith a small article dealing with the possibilities of dwarf coco-nuts in New Guinea, and should you consider it suitable for publication hope that it will encourage other planters to express their views through your journal.

Assuring you of my assistance at all times,

Yours faithfully,
(Signed) B. G. Hall.

THE POSSIBILITY OF CULTIVATING DWARF COCO-NUTS IN NEW GUINEA.*

By B. G. Hall.

Now that copra has attained a profitable figure, and the majority of planters are able to run their plantations economically and with a fair margin of profit for their capital outlay, it is found that the coco-nut remains as yet the mainstay of the Territory of New Guinea.

However, despite the recovery of the copra market, it should be the duty of every planter who takes an intelligent interest in the development of his property, to investigate ways and means of increasing his returns still more from coco-nuts, and if he has decided to plant a further area of this crop, consideration should be given, where conditions appear suitable, to the planting of Malayan dwarf varieties. It must be clearly understood that the writer by no means suggests that the dwarf variety should be planted in preference to the ordinary "tall" palm, but feels that the dwarf coco-nut offers a most interesting subject for careful consideration, and, no doubt, there are areas in New Guinea, such as Kar Kar Island and Talasea, where it would thrive.

The following opinions and information, which have been obtained from outside sources, may prove interesting to planters who are more or less interested in this variety of coco-nut palm.

Varieties of Malayan Dwarf Coco-nut.

As yet there has been no known variety of dwarf coco-nut classified as being peculiar to New Guinea, and the few odd palms which may be found in the Territory have been obtained in a majority of cases from the Solomon Islands, where several areas of so called "King" coco-nuts have been planted.

In Malaya there are three recognized varieties under cultivation, namely—

Dwarf yellow,
Dwarf red,
Dwarf green,

which are characterized by the colours as specified. The yellow variety appears to be most popular, and the heavier producer, and some remarkable production figures have been obtained from this variety, under ideal conditions, particulars of which will be given later.

Soil.

It appears that the soil must be the best available, in accordance with the usual rules governing coco-nut culture, but no doubt average soils, properly treated by the establishment of cover crops such as *Centrosema pubescens, pueraria* or *calopogonium,* or other leguminous covers, together with careful and efficient drainage, and if considered necessary forking, would produce most satisfactory results.

Planting Distance.

This variety is a dwarf in every respect, and its growth is approximately half that of the ordinary "tall" variety, so that the distance of planting may be much closer, and consequently the number of palms per acre is increased and under favorable conditions the output per acre.

* *Editorial Note.*—This subject has been dealt with in detail by the Economic Botanist as a sub-section in his article "Coco nut Improvement" appearing in this issue. Mr. Hall's article, however, is presented in a popular way.

It is the practice in Malaya, and I have been recommended likewise, to plant approximately 22 feet x 22 feet square giving 90 palms to the acre, but the writer personally would suggest planting 22 feet x 22 feet on the equilateral triangle, thus obtaining more palms per acre, and making greater use of the ground available.

It is an accepted fact that there is nothing to be gained by giving a palm more ground area than it actually requires for its normal development, and therefore, from information obtained from the *Malayan Agricultural Journal*, it appears that 22-ft. planting was quite sufficient when the area was extensively drained and irrigated, with *Centrosema pubescens* established over the whole area, and the matter of planting on the square or triangle is purely a matter of taste. It has been asserted by one authority(1) that spacing 15 feet x 15 feet has given the best results. However, the writer is of the opinion—influenced by personal observations of the coco-nut palm and advice from Malaya regarding the dwarf variety—that the closer planting may give greater yields during the first few years of bearing, but the larger distance would as the palms grew older produce more heavily and have a longer span of life, which is a most important factor to be considered with any crop.

Yield.

Under ideal conditions, some remarkable yields have been obtained, and some very interesting figures were published recently in the *Malayan Agricultural Journal* regarding an area of 41 acres, planted in 1920, which has been extensively drained, irrigated at intervals, and had cover crop established throughout, the cover plant proving most suitable being *Centrosema pubescens*. The soil was coastal alluvial clay, which in an undrained condition was grey in colour on the surface, changing to blue or blue grey a few inches below the surface down to the water table and further. This type of soil is quite common in New Guinea. After proper drainage and efficient aeration of this soil—establishment of cover crops—it was observed that a complete change took place and the soil showed itself as rich in all plant foods, the quantity of which was governed only by the depth of drainage, and was most suitable for the cultivation of coco-nuts. This area, as will be seen from the following figures, responded magnificently to this treatment, and will serve to give some idea as to the possibilities of this variety of coco-nut palm:—

Year.	Number of nuts harvested.	Average number of nuts.	Copra per acre.	Number of nuts.
		Per palm.	Cwt.	Per cwt.
1925	194,530	56	9	508
1926	235,360	67.5	11	509
1927	209,876	60	8	622
1928	386,876	111	17	560
1929	235,444	67.5	10	509
1930	368,056	106	17	508
1931	371,645	106.5	17	508
1932	345,208	99	18	448
1933	514,091	148	30	386
1934	470,028	135	28	387
1935	531,219	152	32	386

It appears that from 1931 onward extensive irrigation was carried out on the area, with the results as illustrated in table above. The average over the eleven years from 1925-1935 was 17.9 cwt. per acre, or 44.7 cwt. per hectare, which is really phenomenal, and it will be noted that when the area first came into bearing in 1925, the output was at the rate of 9 cwt. per acre or 22.5 cwt. per hectare, which when we consider that a New Guinea plantation producing 1 ton per hectare when fully bearing is considered a very good property, exemplifies the fact that the dwarf variety should be given further consideration as an economic crop in New Guinea. When observations were last taken in 1935, this area was producing approximately 4 tons per hectare, and with corresponding care and attention to their cultivation, the writer is of opinion that yields of 3 tons per hectare in parts of New Guinea should not be an impossibility. The cultivation of the dwarf coco-nut in New Guinea is as yet purely a matter for conjecture, and experimental plots would necessarily have to be planted before its adoption by private planters could be recommended.

Despite the aforementioned excellent results obtained in Malaya, the fact must not be overlooked that there are many drawbacks which tend to counterbalance the main advantage offered by dwarf coco-nuts of giving a crop after five years, compared with eight to ten as is the case with the "tall" palms. The chief disadvantage being the fact that the dwarf variety does not remain in bearing as an economically profitable crop nearly as long as the "tall" variety, a factor which is most important, but which may be equalized by greater production per hectare. And again, it is generally accepted that copra produced from dwarf varieties is, as a rule, inferior to that of the "tall" palm, a fact which can reflect in numerous ways.

From information received from the Department of Agriculture, Kuala Lumpur, in regard to the dwarf coco-nut in Malaya, it appears that this variety is very susceptible to any unfavorable factors, and adequate rainfall, suitable soil, efficient drainage, together with careful cultivation, are absolutely essential to its successful cultivation. Where we find the ordinary "tall" palm living in soil waterlogged for a considerable period of the year, and still bearing quite favorably, under the same conditions any attempt to cultivate "dwarf" palms would be disastrous and could not possibly meet with success.

In regard to the possibility of cultivating the dwarf palm in New Guinea, we have, undoubtedly, excellent soils and abundant rainfall, and the matter of drainage and cultivation is a matter which rests in the hands of the person controlling the area, and his attitude towards such matters. The question of drainage is a matter not entirely understood by many planters, and as this is a most important and vital phase of cultivation in connexion with the "dwarf" palms, as well as the "tall", a few remarks on this matter would not be wasted.

Drainage.

It must not be considered that when drainage is referred to, that this means the absolute removal of all water from the soil, but when referred to in connexion with the cultivation of coco-nuts interpreted as simply meaning that there is movement of water in the soil as opposed to stagnation, and it has been well established by such authorities as Copeland and Sampson[2] that movement of soil water is most essential to ensure proper development and growth of the coco-nut palm.

The subject of drainage has been ably described in the *Malayan Agricultural Journal* by Messrs. Wardlaw and Mason[3] in which they state, *inter alia* –

> In the case of coco-nut cultivation the writers would consider a well-drained soil one in which there is a constant soil water movement, but this movement should be very slow, in fact, a bare seepage, and by no means of such a nature as to result in washing the soil, as this might prove to be harmful.
>
> If no movement takes place, then steps should be taken either by additional drains, or the planting of suitable covers to rectify matters. A badly-drained soil will be one in which soil water movement was non-existent, thus giving a "still" or stagnant water table near the surface, conditions under which coco-nuts will not thrive for long.

Taking into consideration the requirements of this variety of coco-nut palm, and noting to what extent they can be satisfied by conditions in New Guinea, there is really no reason why the successful cultivation of this "dwarf" could not be undertaken, and careful research and experiment by the Department of Agriculture or the large planting interests are well warranted, as good coco-nut land in New Guinea, although not scarce, is becoming more difficult to obtain, and the planter is now, more than ever, desirous of obtaining the maximum return from his available land.

LITERATURE CITED.

(1) Duncan—*Pacific Islands Monthly*, 21st December, 1936.
(2) E. B. Copeland—*The Coco-nut.* H. C. Sampson—*The Coco-nut Palm.*.
(3) H. H. Wardlaw and F. R. Mason—*Malayan Agricultural Journal*, September, 1936.

REPORT ON SOME DUST AND MUD DEPOSITS RESULTING FROM THE RECENT VOLCANIC ERUPTIONS AT RABAUL, ISLAND OF NEW BRITAIN, NEW GUINEA.

By J. S. Hosking, Division of Soils, Council for Scientific and Industrial Research.

Seven samples representing dust, mud and ash deposits derived from the recent volcanic eruptions at Rabaul have been examined.

The deposits vary in texture from sandy loams to loams bordering on clay loams. The dust deposits from the Vulcan Island Crater, and the rain-washed and sorted material, fall within the former class, and the hardened mud and compacted ash from Matupi Crater, fall within the latter class; the mud layer from Matupi is intermediate in texture. The deposits have an extremely floury consistency, being composed mainly of fine sand and silt; the ratio of fine sand to silt varying from 2:1 to 3:2. The washed and sorted material is the only sample showing any appreciable concentration of coarse pumiceous sand. All materials are highly abrasive.

No free acid is present in the deposits which vary in reaction from slightly acid (pH 5.0) in the Matupi mud layers to slightly alkaline (pH 7.7) in the underlying Vulcan Crater dust layers. The washed and sorted deposit from Vanalea is the most alkaline with a pH of 7.9.

The deposits were examined for soluble salts, 200 gms. of each being extracted with 1 litre of distilled water. The total salt content varied from about 3 per cent. in the more acid deposits from Vulcan Crater to about 1 per cent. in the alkaline Matupi mud layers. The washing of the Vanalea deposit has resulted in marked leaching of this material, less than 0.1 per cent. of salt being present.

Calcium sulphate (gypsum) and sodium chloride constitute the bulk of the soluble salts, although potassium and magnesium salts are also present. The total content of calcium sulphate in the deposits is, undoubtedly, higher than the figures given, since the water extract for those soils showing the greater concentrations have reached approximate saturation. An examination of the figures for loss on acid treatment indicates, however (by subtracting the remaining soluble salts), an upper limit to the content.

While the content of calcium sulphate is a natural result of volcanic activity the high content of sodium chloride is probably due to contamination with sea water.

The effect of heavy rains in the rapid removal of salts is evident when the content for the deposit from Vanalea Village is compared with the remaining samples.

Analytic details for the seven samples are given in the Table.

MECHANICAL ANALYSES OF, AND WATER SOLUBLE SALTS IN, THE VOLCANIC DEPOSITS FROM RABAUL, NEW BRITAIN, NEW GUINEA.

Field Sample Number.	1.	2.	3.	4.	5.	6.	7.*
Waite Institute Number.	5202.	5203.	5204.	5205.	5206.	5207.	5208.
Nature of Deposit.	Dust (protected from rain).	Mud Layer overlying No. 3.	Dust Layer underlying No. 2.	Composite Sample of Nos. 2 and 3.	Hardened Mud.	Compacted Ash.	Deposit washed and sorted by Thunder Storms.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Coarse Sand	7.4	4.5	13.3	6.4	3.0	13.4	32.5
Fine Sand	58.7	47.9	52.0	49.1	37.6	36.3	36.4
Silt	28.1	29.5	29.0	30.7	30.8	23.5	26.1
Clay	4.7	9.6	4.6	8.5	21.0	16.5	4.8
Loss on acid treatment	2.2	6.4	1.8	5.0	6.7	7.8	0.7
Moisture	0.8	2.7	0.7	2.2	2.3	3.0	0.4
Loss on Ignition ..	1.9	3.1	1.7	2.4	2.9	4.5	1.5
Reaction pH	7.3	5.0	7.7	5.1	7.1	5.8	7.9
Soluble Salts†—							
Chloride .. ion CL′ ..	0.46	0.69	0.34	0.49	0.13	0.49	0.035
Sulphate .. ion SO_4 ..	0.37	1.08	0.30	1.01	0.89	1.33	0.020
Calcium .. ion Ca″ ..	0.20	0.50	0.13	0.50	0.46	0.46	0.009
Magnesium ion Mg″..	0.03	0.09	0.03	0.07	0.04	0.15	0.001
Sodium .. ion Na′ ..	0.22	0.32	0.17	0.25	0.08	0.28	0.018
Potassium ion K′ ..	0.02	0.04	0.02	0.03	0.03	0.05	0.006
Manganese ion Mn″..	0.001	0.006	0.002	0.005	0.004	0.013	0.000
Carbonate ion Co_3 ..	0.001	0.000	0.000	0.000	0.001	0.000	0.001
Total	1.30	2.73	0.99	2.36	1.63	2.77	0.090
Salts expressed as—							
Gypsum $CaSO_4 2HO$ ..	0.66	1.93	0.54	1.81	1.59	1.97	0.036
Sodium Chloride NaCL	0.56	0.81	0.43	0.64	1.26	0.71	0.046

* This sample contained 8 per cent. pumiceous stone. † 200 gms. of deposit extracted with 1 litre of distilled water.

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TERRITORY OF
NEW GUINEA
ADMINISTERED BY THE COMMONWEALTH UNDER MANDATE FROM THE LEAGUE OF NATIONS
SCALE OF MILES
0 50 100 150
BISMARCK
MANUS
ADMIRALTY
ISLANDS
ARCHIPELAGO
NEW IRELAND
NEW BRITAIN
KIETA
NORTH EAST NEW GUINEA
SEPIK
MADANG
MOROBE
PAPUA
DUTCH NEW GUINEA
MANU I.
AUA I.
WUVULU I.
NINIGO GROUP
Lorengau
C. Siemens
MUSSAU I.
ST MATTHIAS GROUP
ISABEL CHANNEL
LAVONGAI I.
Kavieng
TABAR IS
LIHIR I.
TANGA IS
NUGURIA IS
FENI IS
Namatanai
ST. GEORGES CHANNEL
RABAUL
C. Lambert
Kokopo
C. St George
Kailai
Owen Pt.
NISSAN IS
C. Henpan
BUKA I.
Sohana
Buka Passage
Inus
BOUGAINVILLE I.
Kieta
Mutupina Pt.
Vanimo
Aitape
KAIRIRU I.
MUSHU I.
Wewak
SCHOUTEN ISLANDS
Marienberg
Bieng
MANAM I.
KARKAR I.
BAGABAG I.
Madang
LONG I.
UMBOI I.
DAMPIER STRAIT
VITU ISLANDS
C. Gloucester
C. Campbell
KIMBE BAY
Talasea
Gasmata
Helsbach
C. Cretin
Lae
HUON GULF
Salamaua
Morobe
Mt Blucher
Mt Hagen
PORT MORESBY
0°
3°
6°
9°
141°
144°
147°
150°
153°
156°
DRAWN BY PROPERTY & SURVEY BRANCH, DEPT OF THE INTERIOR CANBERRA, 1937.